Surfaces Of Revolution (S .O .R)

الأسطح الدورانيه

نسألكم الدعاء

IF you download the Free ***APP.*** **RC Structures** YASSER EL LEATHY *on your smart phone or tablet, you will be able to play illustrative movies For any paragraph that has a QR code icon*

اذا حملت تطبيق **RC Structures** YASSER EL LEATHY على تليفونك المحمول او اللوح السطحى ستستطيع أن تشغل أفلام شرح للمقاطع التى تحتوى على رمز

Surfaces Of Revolution Table of Contents.

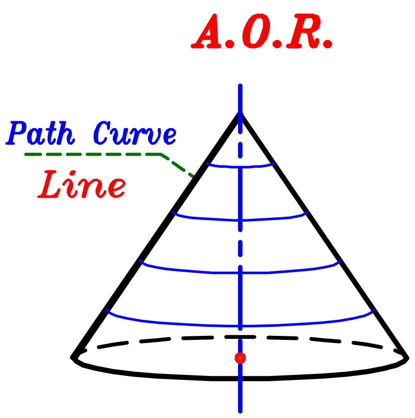
Surfaces Of Revolution (S.O.R.)

Introduction.

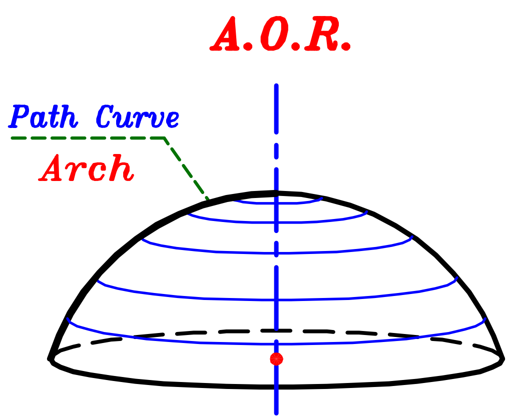
هى عباره عن أسطح رفيعة (غشاء) تنشأ من دوران منحنى (Path Curve)
حول محور رأسى يسمى محور الدوران (A.O.R.) Axis Of Revolution

و ال (Path Curve) عباره عن المنحنى الذى يدور أفقيا دوره كامله
و ممكن أن يكون خط مستقيم أو قطعه من دائره (Arch) أو قطع ناقص (Parabola)
أو أى منحنى أخر .

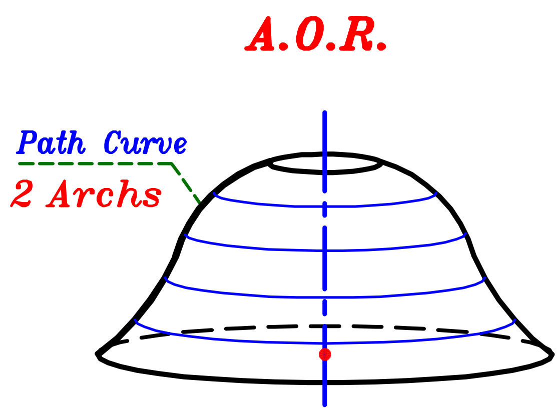
*Surfaces Of Revolution is a surfaces has a membrane behavior created by rotation of a curve called **Path Curve** around vertical axis called **Axis Of Revolution** (A.O.R.)*



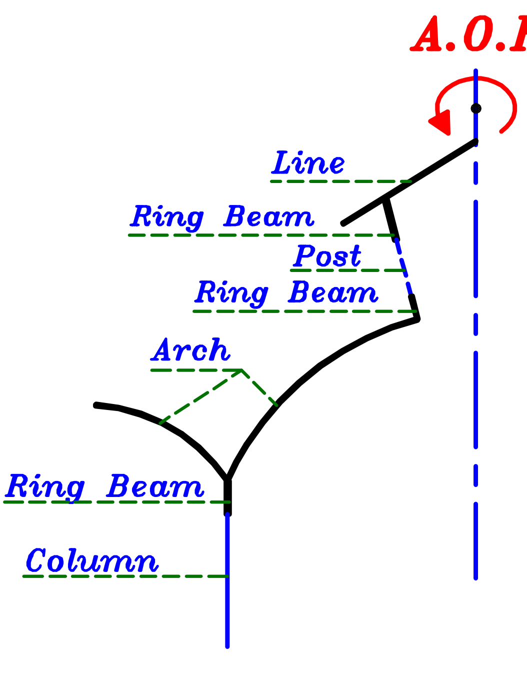
Cone

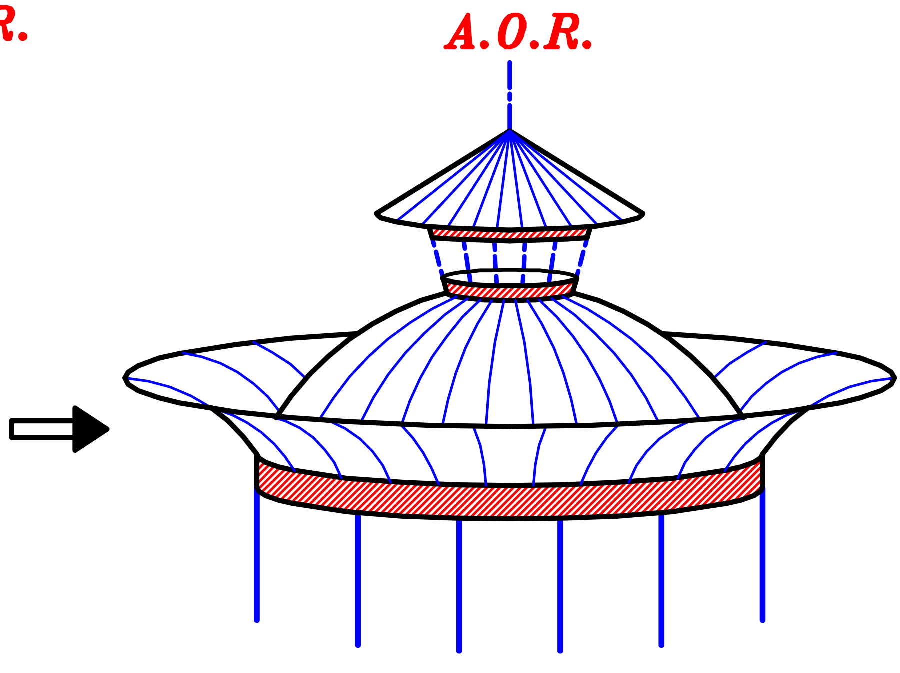


Dome



Bell shape



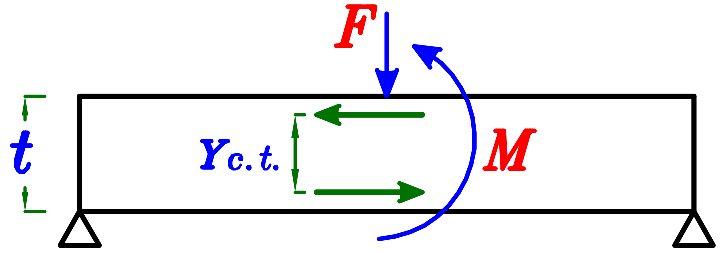


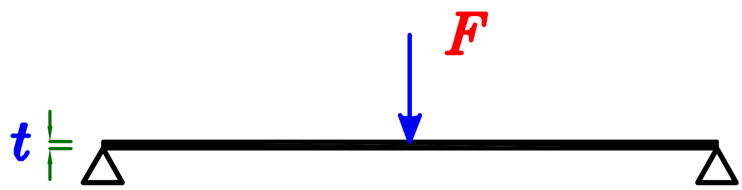
Membrane Theory.

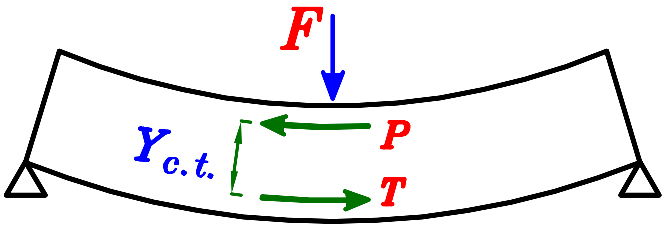
نظريه الغشاء (القشره)

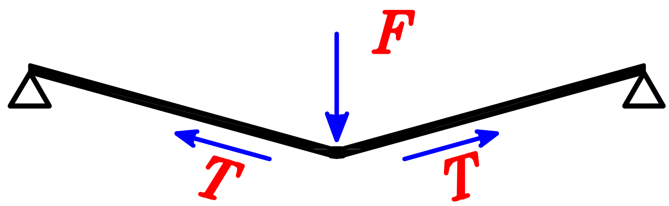
Beam or slab thickness (t) has a big value.

Shell (membrane) thickness (t) has a very small value.









Bending Moment

Compression & Tension

Axial Force

Compression only
or
Tension only

نظرا لصغر سُمك الأشكال القشريه (Shells) و صغر سُمك الأسطح الدورانيه فعند تعرضها للاحمال لن تكون هناك تخانه (t) كافيه ليحدث لها Bending أى أن يحدث لجزء Compression و الاخر Tension لكن الاحمال المؤثره تسبب ان يكون كل القطاع معرض اما لـ Compression فقط او لـ Tension فقط.

أى أن الـ Inertia للقطاع صغيره جدا فلا يكون هناك Bending Rigidity.
فتقاوم هذه المنشأت الأحمال الواقعه عليها عن طريق (Axial Forces) فقط
و لا توجد مقاومه للـ (Bending Moments)

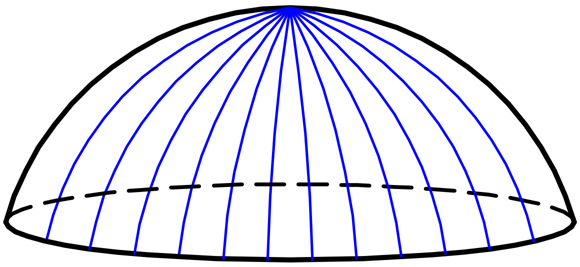
Because of the very small thickness of the shell, it works as a membrane, Which has No Bending Rigidity. Means NO Bending Moment acting on the shell. **Only Axial Forces** [Meridian Force (T_1) & Ring Force (T_2)] **acting on the Shell.**

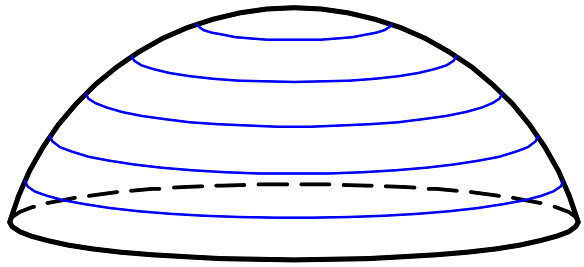
Definitions & Signs.

هناك بعض التعريفات المهمه و الاشارات (الموجبه و السالبه) التى يجب ان نعرفها أولا .

* Meridian Direction & Ring Direction.

و هى عباره عن اتجاهات القوى المؤثره على ال **Surface**





Meridian Direction.

هو الاتجاه الطولى (الرأسى)

و يأخذ نفس شكل ال **Path Curve**

Ring Direction.

هو الاتجاه الدائرى العرضى (الافقى)

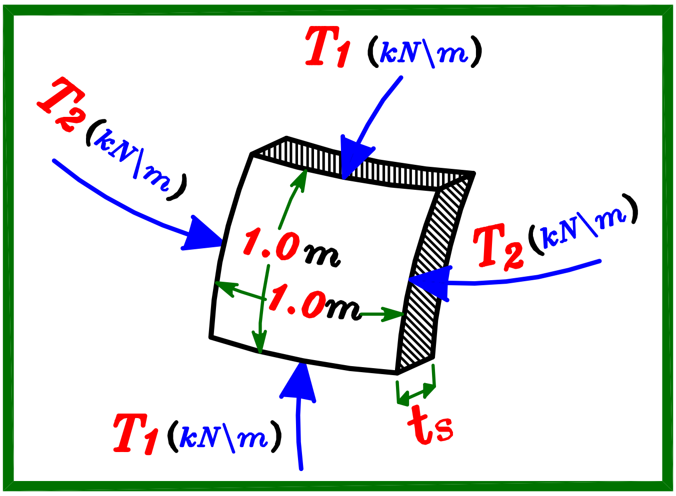
و دائما مركزه هو محور الدوران

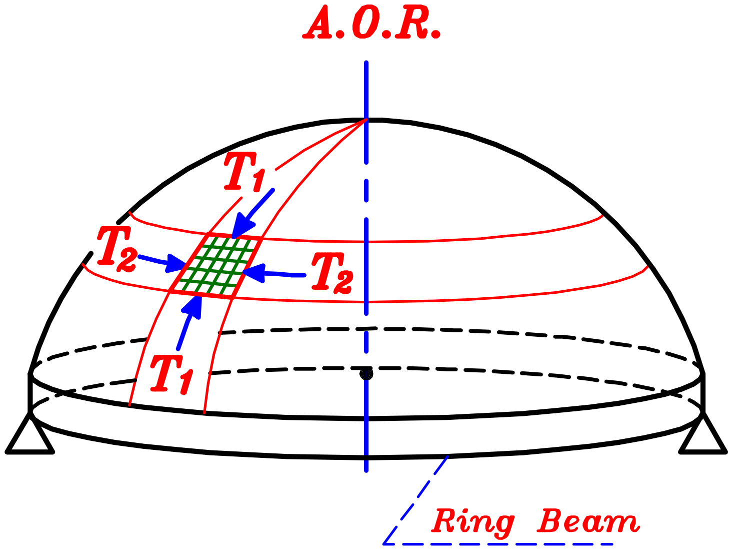
* Internal Forces (T_1) & (T_2).

هى قوى الضغط أو الشد المؤثره على **1.0 m** طولى من السطح فى الاتجاهين اتجاه **Meridian direction** و اتجاه **Ring direction**

T_1 is **Meridian Force.** ($kN\backslash m$)

T_2 is **Ring Force.** ($kN\backslash m$)

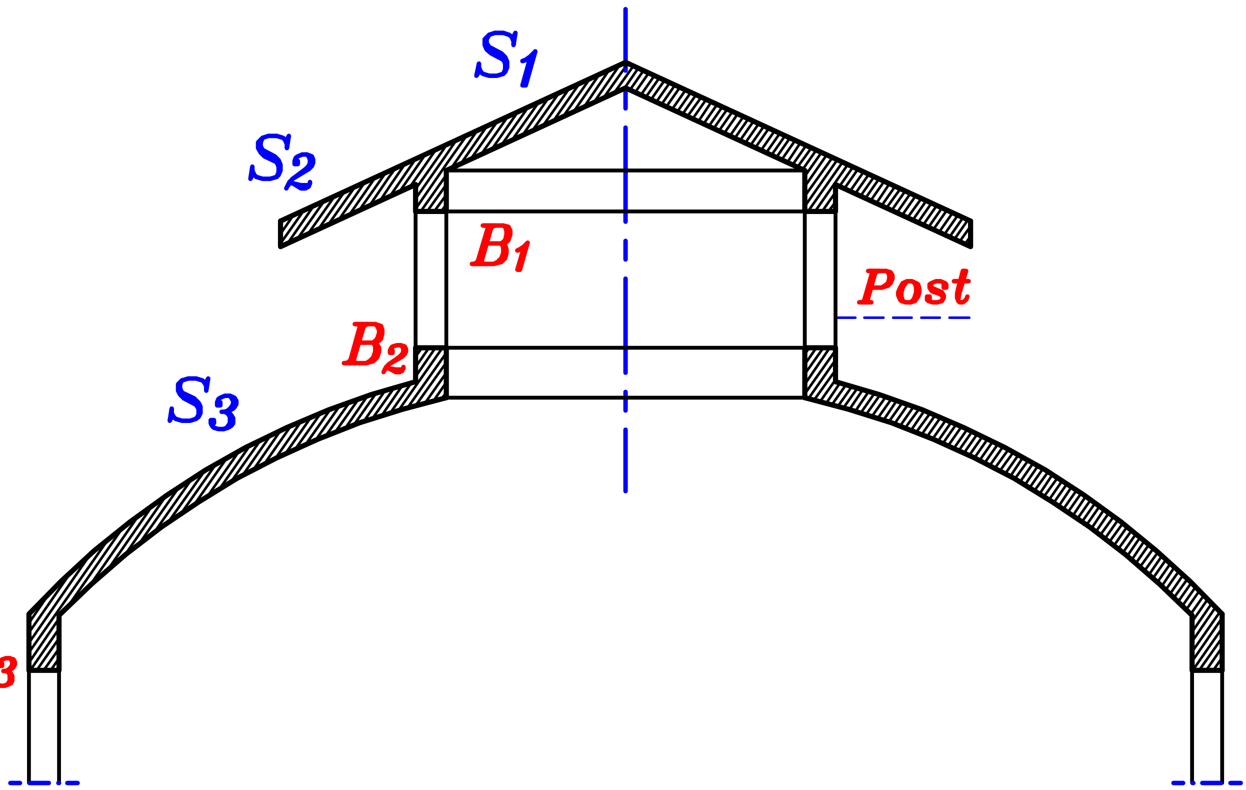


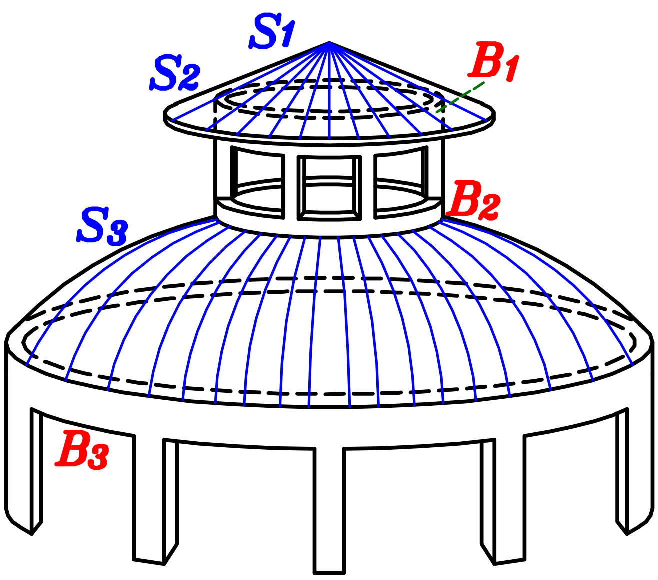


Signs of T_1 & T_2	$+Ve \rightarrow$	**Compression**
	$-Ve \rightarrow$	**Tension**

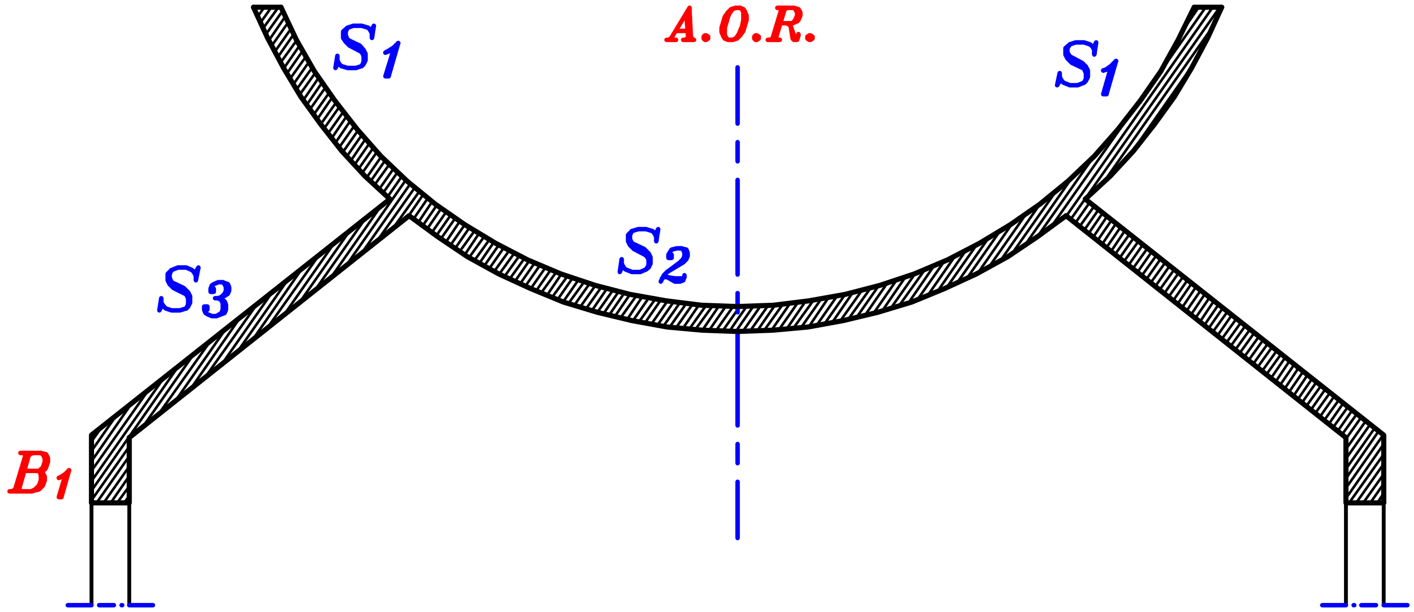
* Shell Surface.

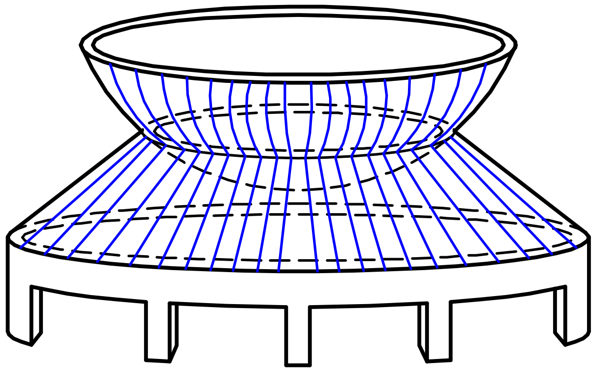
و هى الاسطح الدورانيه التى يكونها ال **path curve**
و تكون دائما محموله على **support** واحد فقط و هو اما كمره دائريه **Ring Beam**
او محموله على سطح اخر .
و يتم تحليل القوى فى كل سطح على حده ما دام بينهم ركيزه **support**





- السطح S_1 محمول على الكمره B_1
- السطح S_2 محمول على الكمره B_1
- الكمره B_1 محموله على ال **Posts**
- ال **Posts** محموله على الكمره B_2
- الكمره B_2 محموله على السطح S_3
- السطح S_3 محمول على الكمره B_3
- الكمره B_3 محموله على الاعمده

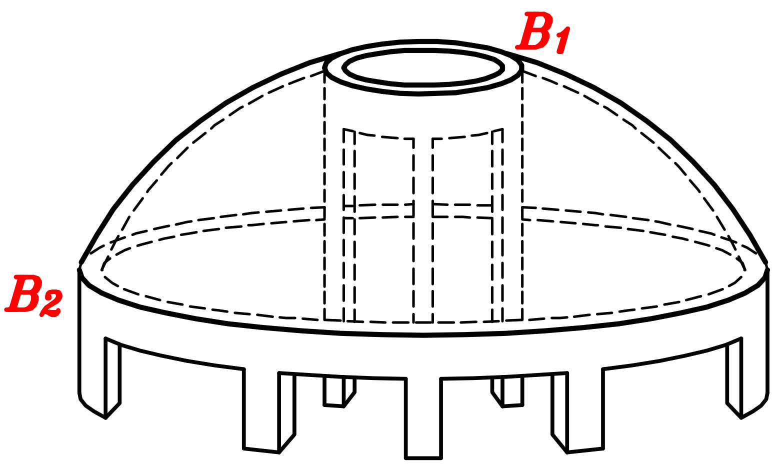


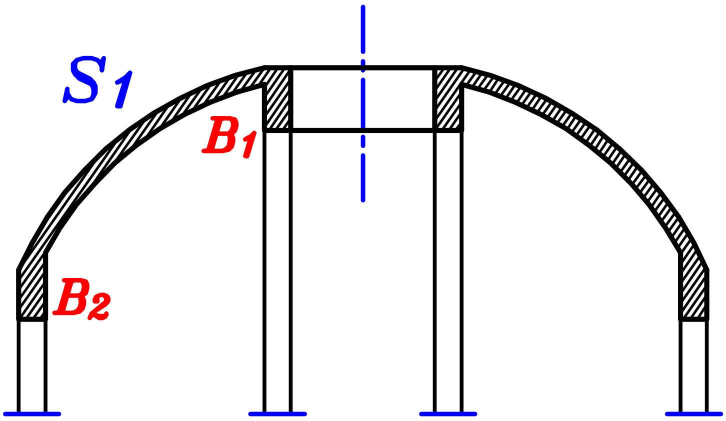


- السطح S_1 محمول على السطح S_3
- السطح S_2 محمول على السطح S_3
- السطح S_3 محمول على الكمره B_1
- الكمره B_1 محموله على الاعمده

ملحوظه هامه .

فى هذا الملف لن نتناول تحليل الاسطح المحموله على اكثر من *support* حيث يتم تحليلها بالكمبيوتر .



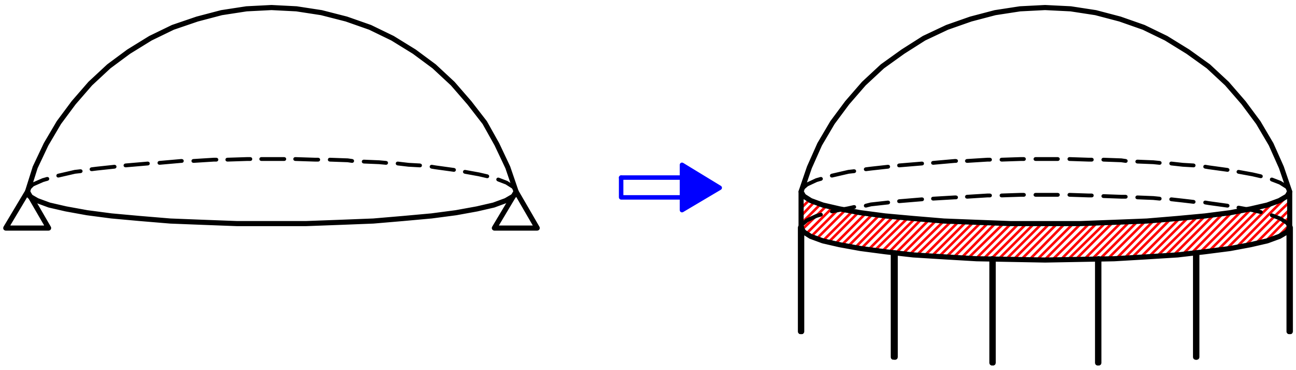


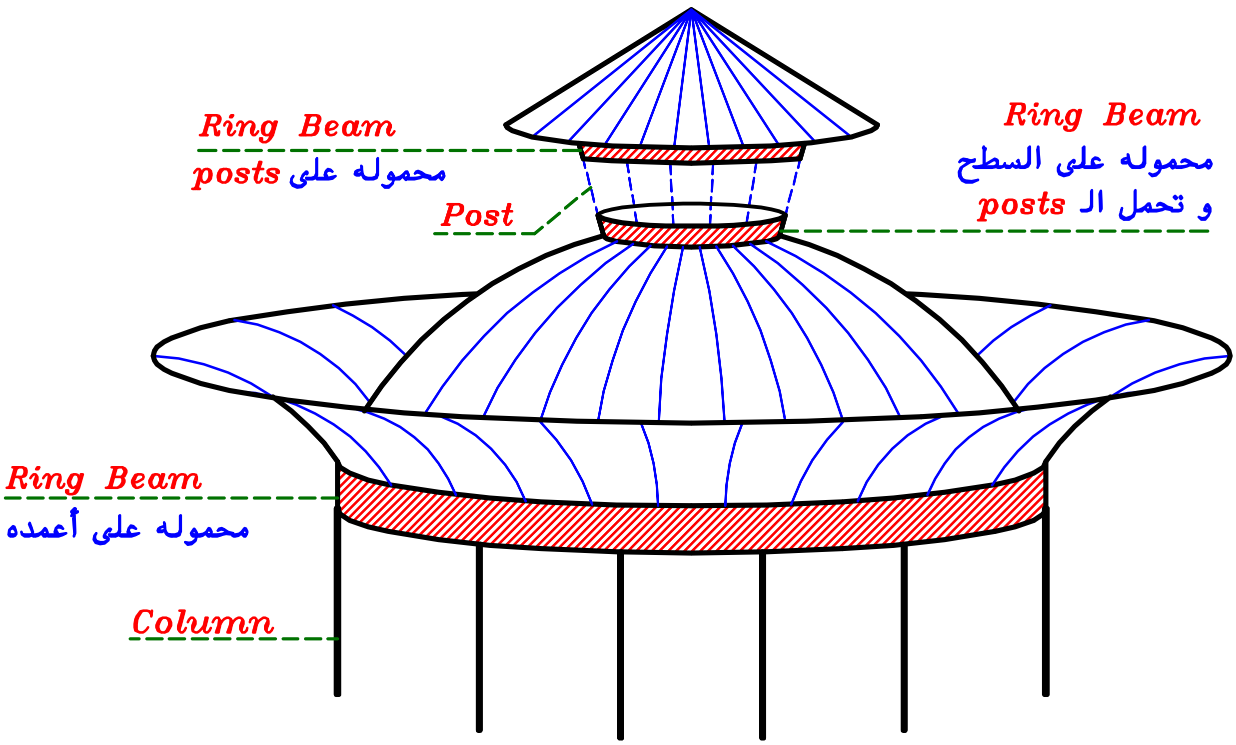
لن نستطيع تحليل السطح S_1 لانه محمول على *2 supports* و هما B_1 & B_2
لذا يجب تحليله بالكمبيوتر

* Ring Beams.

الكمرات الدائريه تعتبر **support** للاسطح الدورانيه .

و تكون محموله على أعمده أو **posts** او تكون محموله على السطح الدورانى و تحمل الـ **posts**

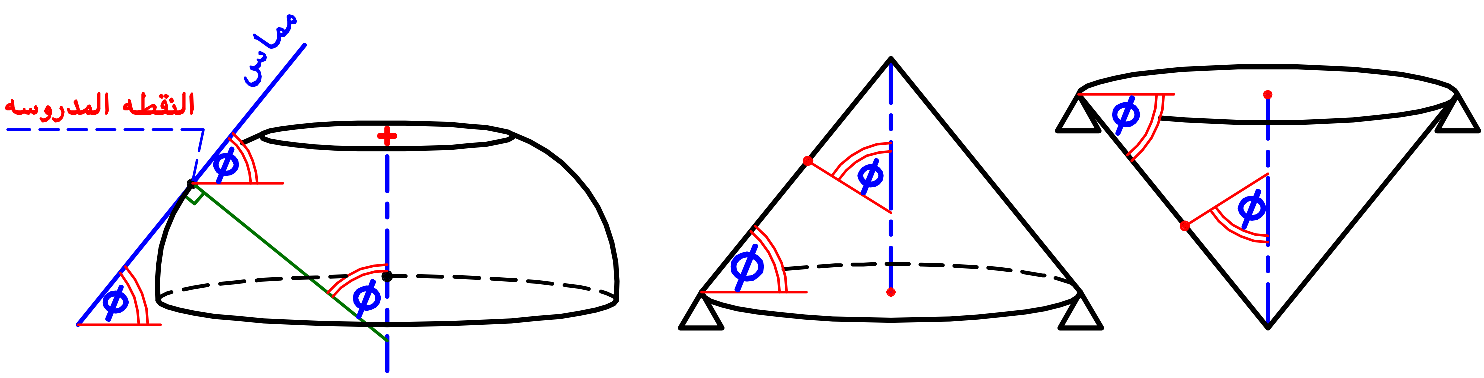




* ϕ

ϕ هى زاويه ميل المماس للسطح عند النقطه المدروسه مع المستوى الافقى .

و فى حاله اذا كان المنحنى عباره عن خط مستقيم تكون الـ ϕ هى زاويه ميل هذا الخط مع الافقى .

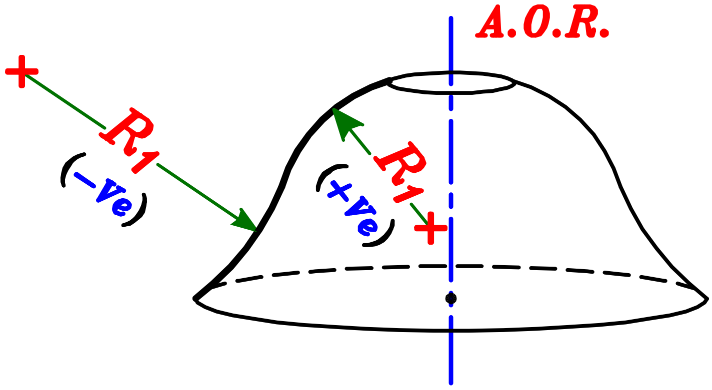


* R_1

R_1 هو نصف قطر المنحنى (*Path Curve*)

R_1 (+Ve) *Sign*
عندما تكون خارجه بعيدا عن ال (A.O.R.)

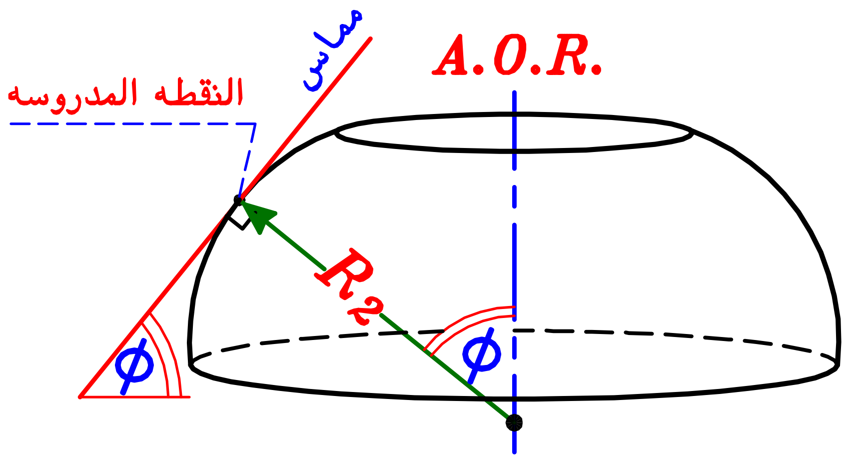
R_1 (−Ve) *Sign*
عندما تكون داخله فى اتجاه ال (A.O.R.)



* R_2

R_2 هو البعد العمودى على المماس من النقطه المدروسه حتى (A.O.R.)
و زاويه ميله مع الرأسى هى ϕ

R_2 دائما اشارتها (+Ve)

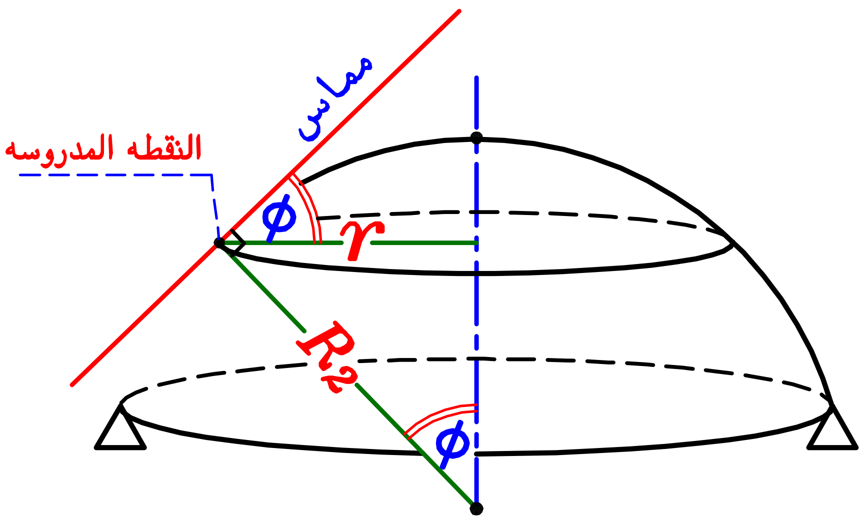


* r

r هو نصف قطر الدائره الافقيه عند النقطه المدروسه

$$\boxed{r = R_2 * Sin\ \phi}$$

r دائما اشارتها (+Ve)

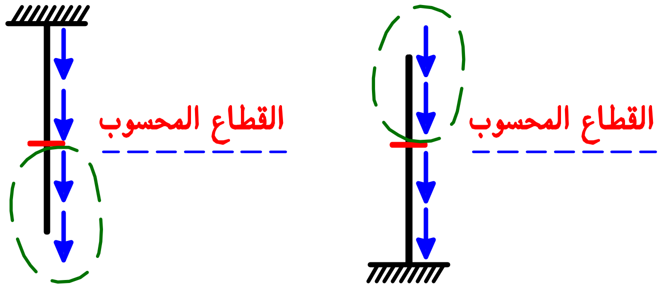


* W_ϕ

W_ϕ هى مجموع الاوزان الرأسيه المسببه لعمل ضغط او شد على السطح .

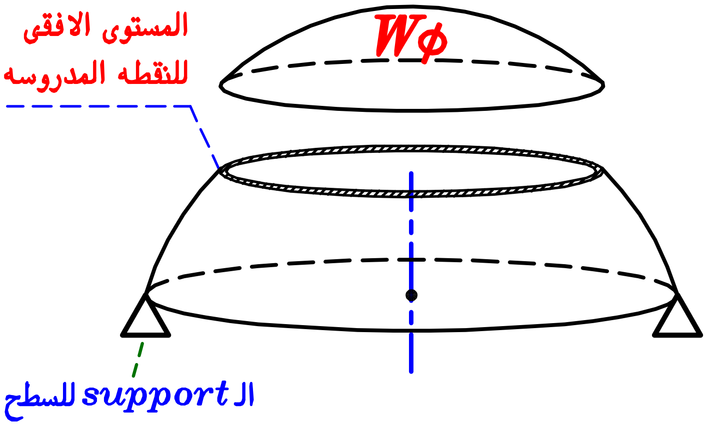
بما ان السطح محمول على ***support*** واحد فقط ، إذاً ممكن لحساب الضغط او الشد عند قطاع معين ان نحسب مجموع الاوزان من جهه الطرف الحر ***Free end***

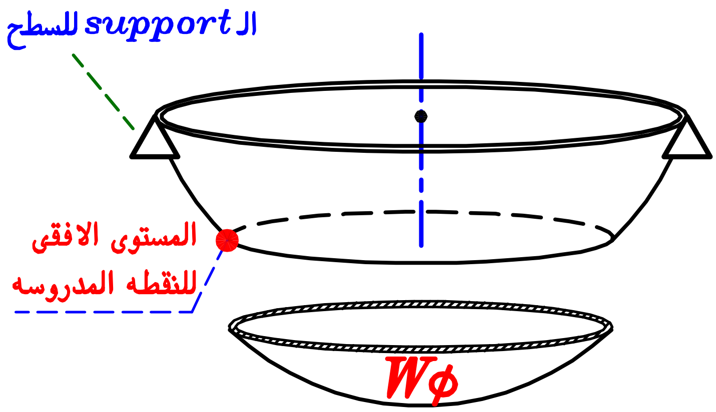
مثل حاله حساب ***Normal Force*** فى ال ***Cantilevers***



إذاً

> W_ϕ هى مجموع الاوزان الرأسيه المحسوبه عند المستوى الافقى عند النقطه المدروسه لسطح معين محسوبه من الجهه البعيده لل ***support*** الذى يحمل هذا السطح .





$$D.L. = g = t_s \, \gamma_c + F.C. = \checkmark \quad (kN\backslash m^2)$$

$$L.L. = P = \checkmark \quad (kN\backslash m^2) \quad H.P. \quad (\textit{Horizontal Projection})$$

$$\textit{Water Weight} = \gamma_w * \textit{Volume} \qquad \boxed{\gamma_w = 10.0 \quad (kN\backslash m^3)}$$

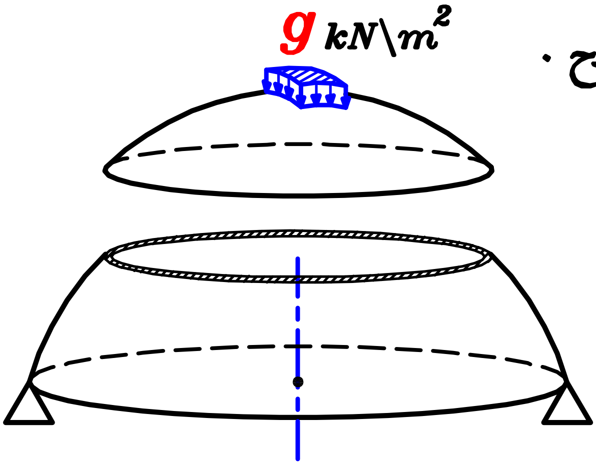
In Case of No Water $\longrightarrow$ $W_\phi = W\phi_{D.L.} + W\phi_{L.L.}$

In Case of Water $\longrightarrow$ $W_\phi = W\phi_{D.L.} + W\phi_{Water}$

$W_{\phi\, D.L.}$

$$D.L. = g = t_s\, \gamma_c + F.C. = \checkmark \quad (kN\backslash m^2)$$

g هى الوزن الواقع على متر مربع من السطح .

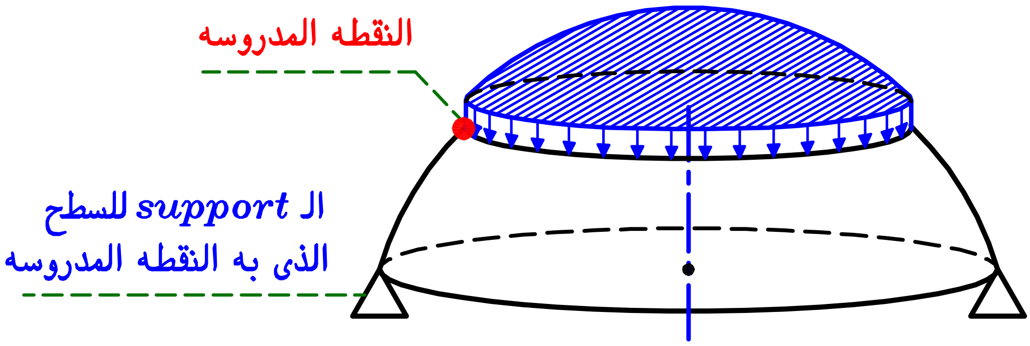


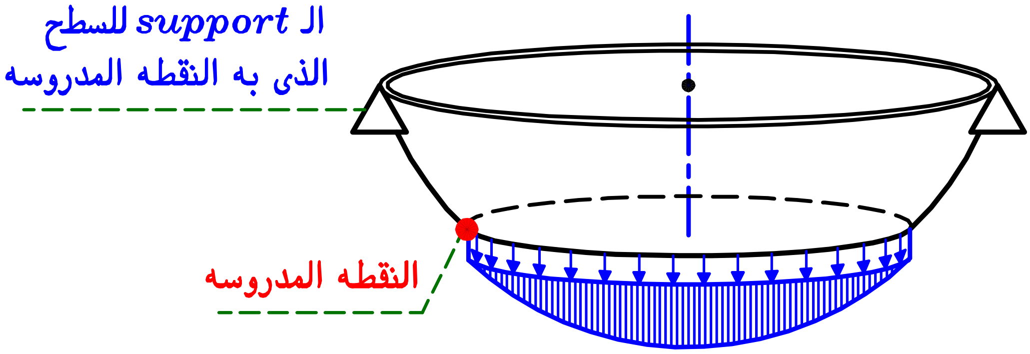
$W_{\phi\, D.L.}$ هو محصله الوزن من الجهه البعيده عن ال support

$$W_{\phi\, D.L.} = g * S.A. = \checkmark \quad (kN)$$

$S.A. = $ Surface Area

$$W_{\phi\, D.L.} = g * \text{Surface Area}$$

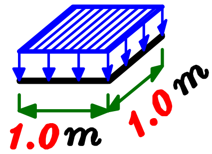




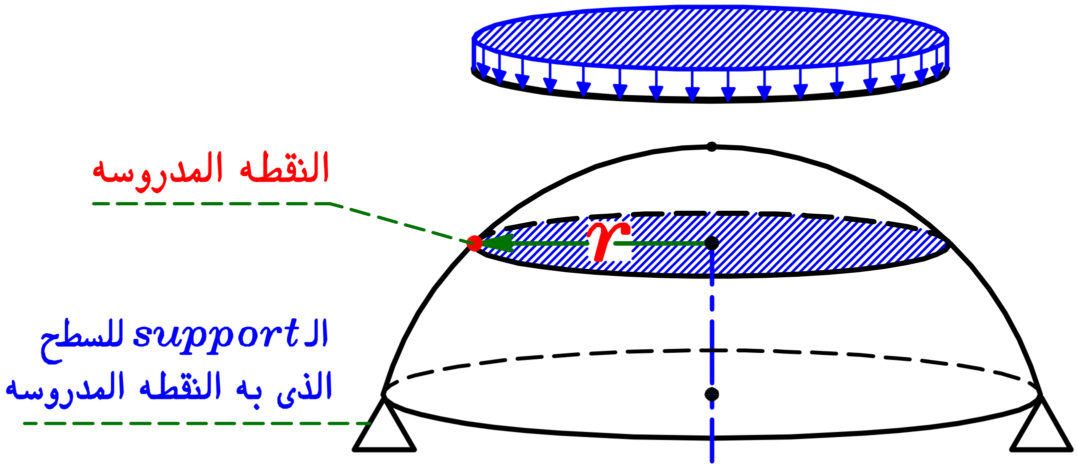
$$W_{\phi\, D.L.} = g * \text{Surface Area}$$

$W_{\phi\,L.L.}$

$L.L. = P = \checkmark\ (kN\backslash m^2)$ H.P. (Horizontal Projection)



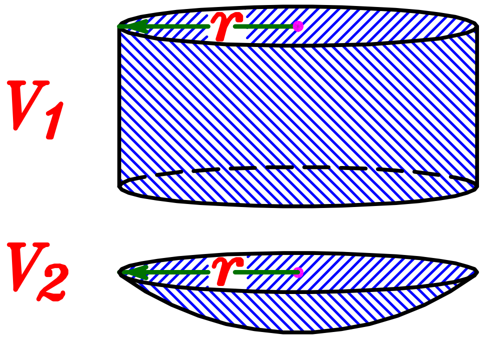
$W_{\phi\,L.L.} = P * \text{Projected Area} = P * \pi\, r^2 = \checkmark\ (kN)$

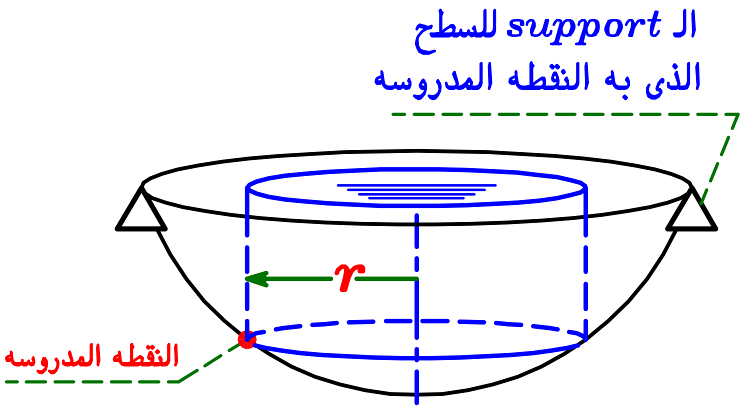


$W_{\phi\ Water}$

$W_{\phi\ Water} = \gamma_w * \text{Volume}$ $\boxed{\gamma_w = 10.0\ (kN\backslash m^3)}$

Volume هو مجموع حجم الماء فوق المستوى الافقى للنقطه المدروسه للسطح من الجهه البعيده لل **support** الذى يحمل هذا السطح .

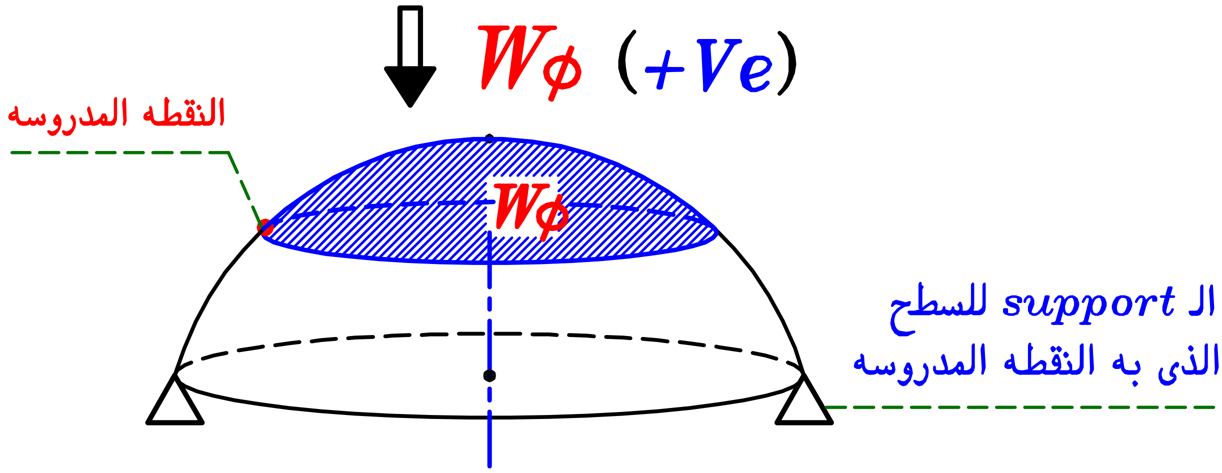




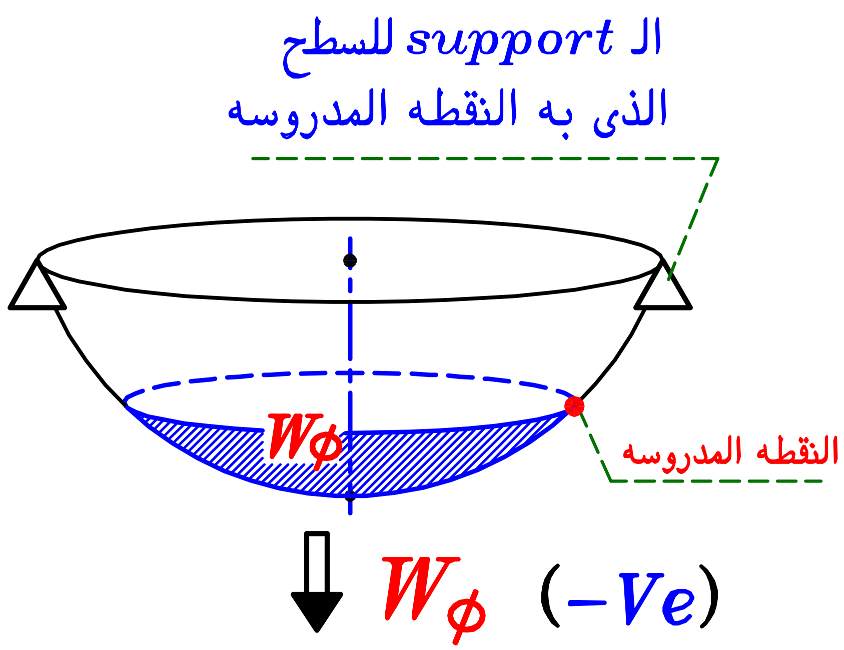
$$W_{\phi\ Water} = \gamma_w * (V_1 + V_2)$$

Signs of W_ϕ

(+Ve) Sign عندما يكون اتجاه ال W_ϕ داخل الى ال **Support**

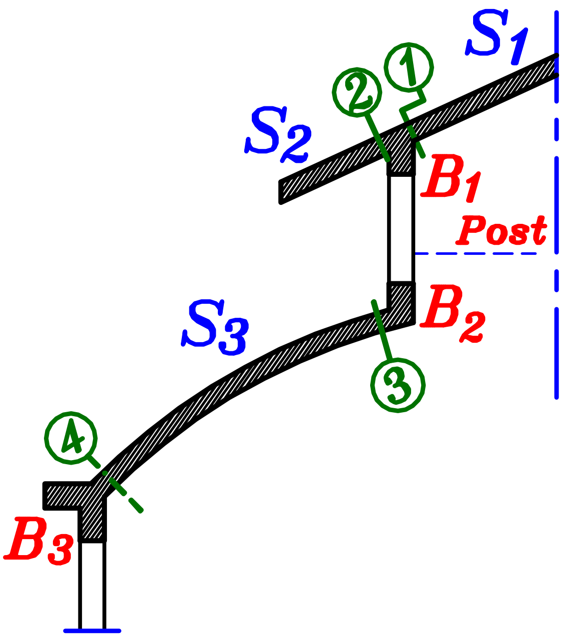


(−Ve) Sign عندما يكون اتجاه ال W_ϕ خارج من ال **Support**



Special Cases of Calculating W_ϕ

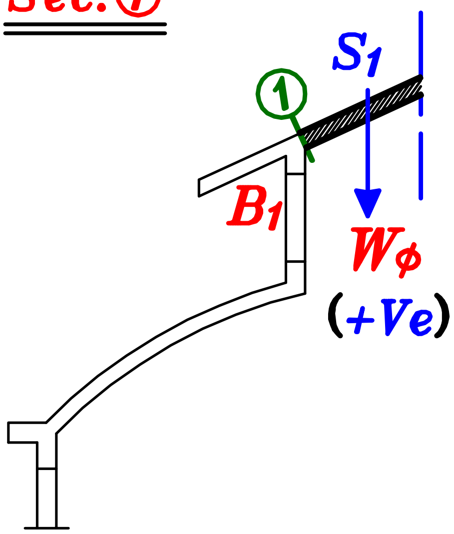
A.O.R.



الكمره B_1 هى ال support للسطحين S_1 & S_2

الكمره B_3 هى ال support للسطح S_3

Sec.①

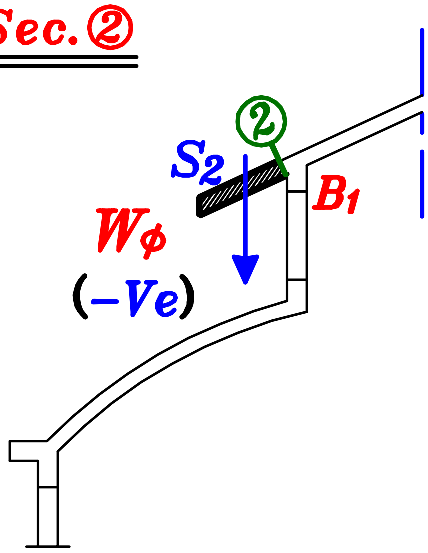


Sec.① موجود فى السطح S_1

الكمره B_1 هى ال support للسطح S_1

$W_{\phi\,(Sec.\,1)}$ = Total Loads on Slab S_1

Sec.②



Sec.② موجود فى السطح S_2

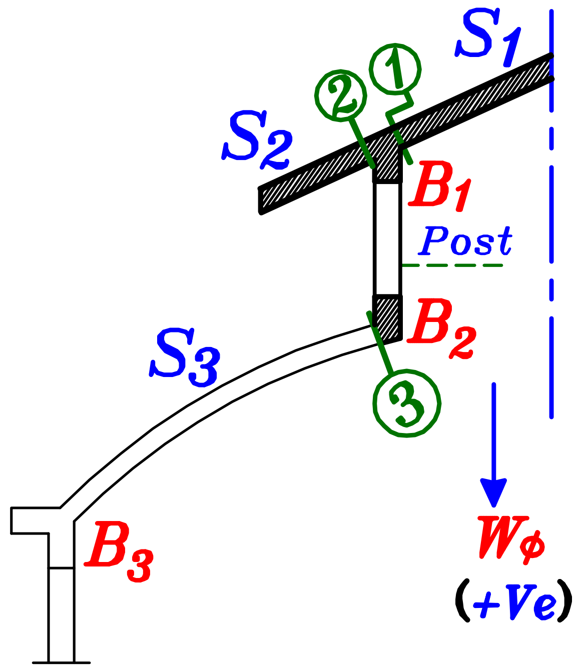
الكمره B_1 هى ال support للسطح S_2

$W_{\phi\,(Sec.\,2)}$ = Total Loads on Slab S_2

Sec. ③

S_3 موجود فى السطح Sec. ③

S_3 الكمره B_3 هى الـ support للسطح



$$W_\phi\ (Sec.\,3) = W_\phi\ (Sec.\,1) + W_\phi\ (Sec.\,2)$$

+ *Total weight of Beam* (B_1)

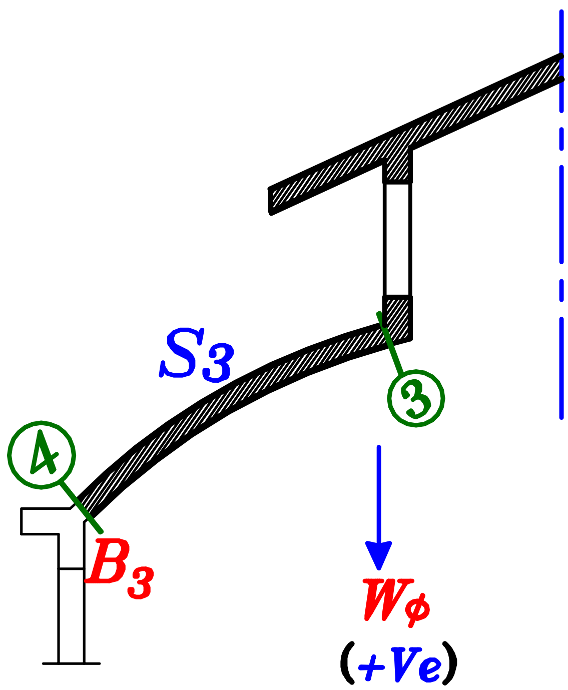
+ *Weight of all Posts*

+ *Total weight of Beam* (B_2)

Sec. ④

S_3 موجود فى السطح Sec. ④

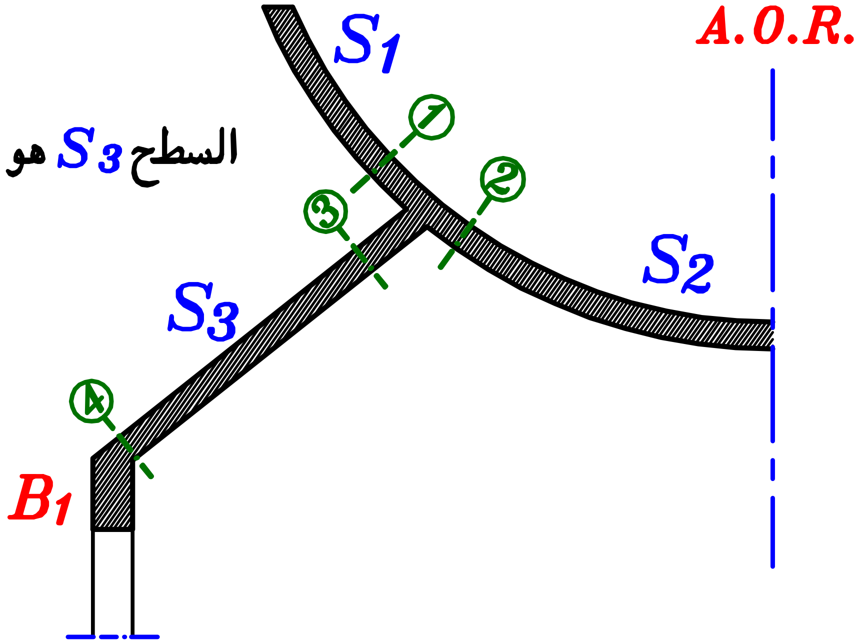
S_3 الكمره B_3 هى الـ support للسطح



$$W_\phi\ (Sec.\,4) = W_\phi\ (Sec.\,3) + \text{Total Loads on Slab } S_3$$

Special Case.

السطح S_3 هو ال ***support*** للسطحين S_1 & S_2

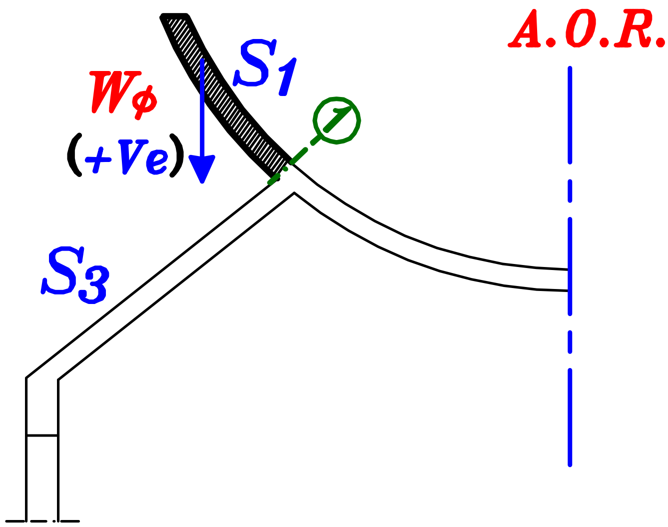


Sec. ①

Sec. ① موجود فى السطح S_1

السطح S_3 هو ال ***support*** للسطح S_1

W_ϕ (Sec. 1) = *Total Loads on Slab* S_1

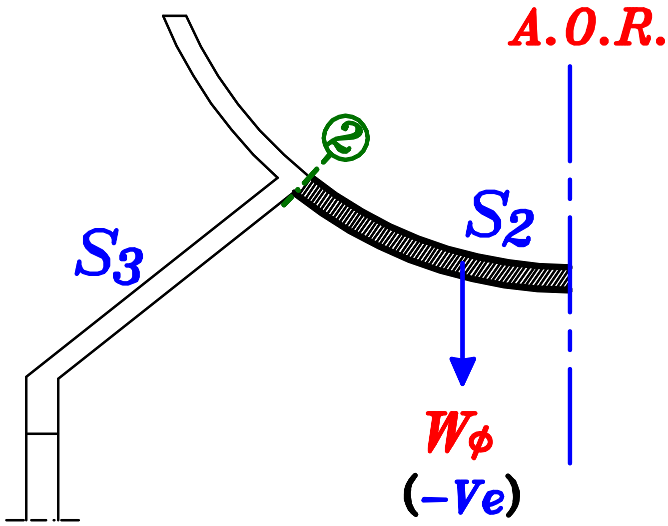


Sec. ②

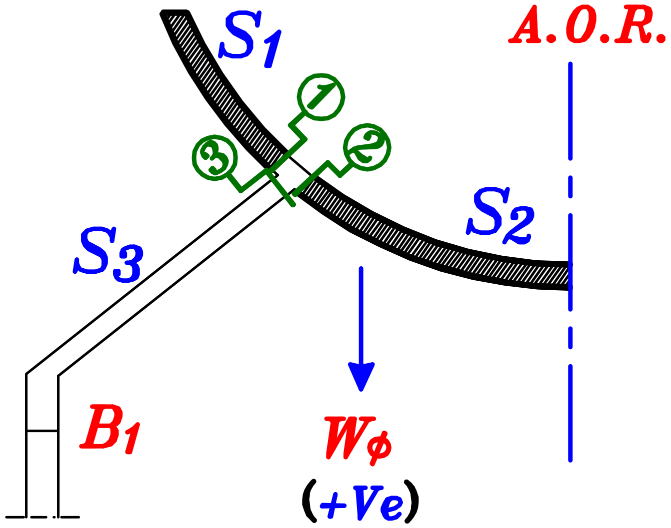
Sec. ② موجود فى السطح S_2

السطح S_3 هو ال ***support*** للسطح S_2

W_ϕ (Sec. 2) = *Total Loads on Slab* S_2



Sec. ③

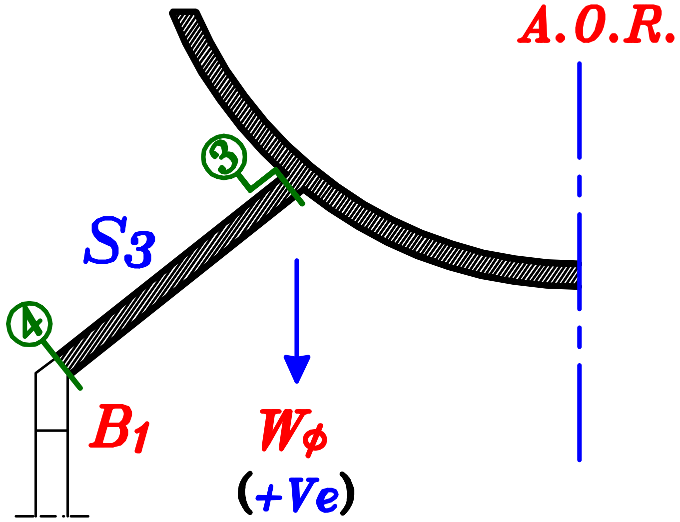


S_3 موجود فى السطح Sec. ③

S_3 الكمره B_1 هى ال support للسطح

$$W_\phi\ _{(Sec.\,3)} = W_\phi\ _{(Sec.\,1)} + W_\phi\ _{(Sec.\,2)}$$

Sec. ④



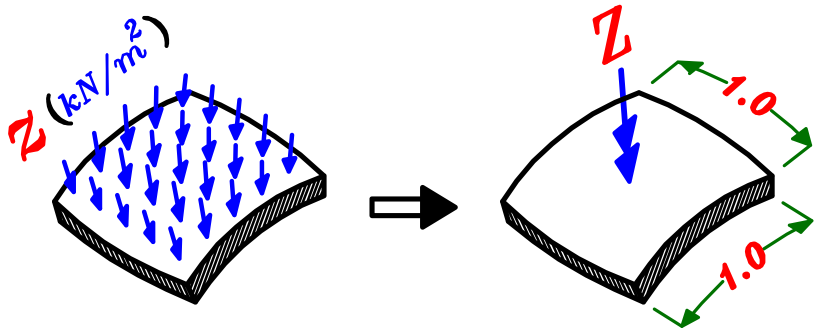
S_3 موجود فى السطح Sec. ④

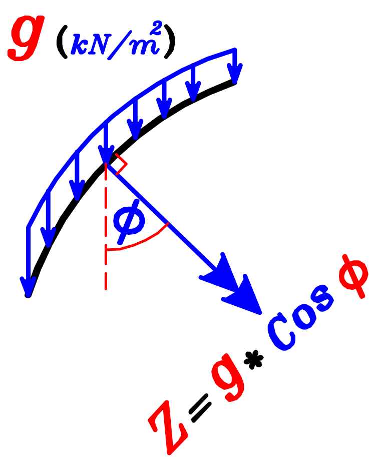
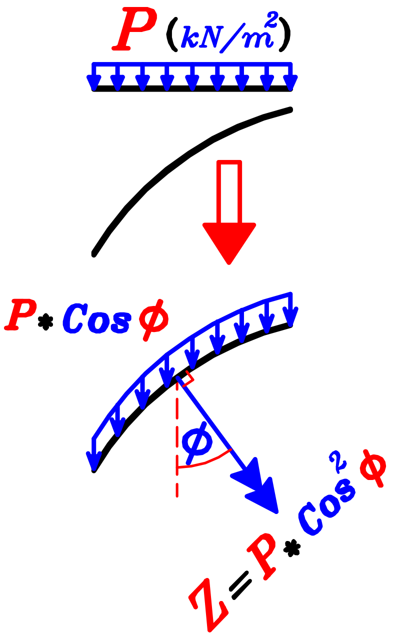
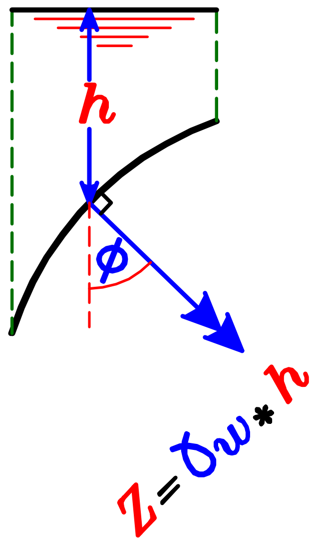
S_3 الكمره B_1 هى ال support للسطح

$$W_\phi\ _{(Sec.\,4)} = W_\phi\ _{(Sec.\,3)} + \text{Total Loads on Slab } S_3$$

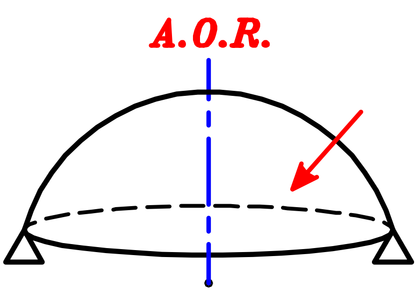
* Z

(Z) هى محصله القوى الخارجيه العمودية على وحده المساحات من السطح .
و وحداتها (kN/m^2)



Dead Load	Live Load	Water Load
		
$Z = g * Cos\,\phi$	$Z = P * Cos^2\phi$	$Z = \gamma_w * h$

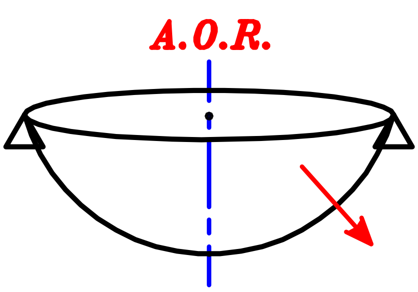
Sign of Z



Z (+Ve) Sign

عندما تكون Z داخله

فى اتجاه ال (A.O.R.)

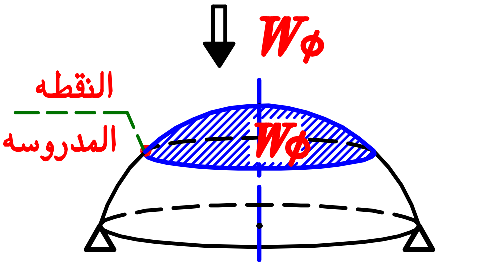
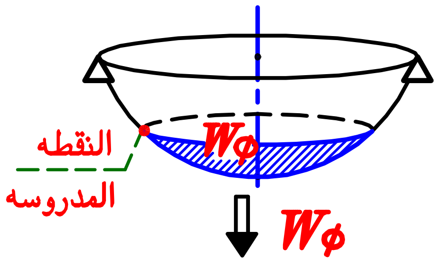
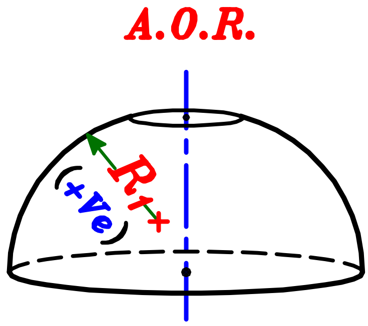
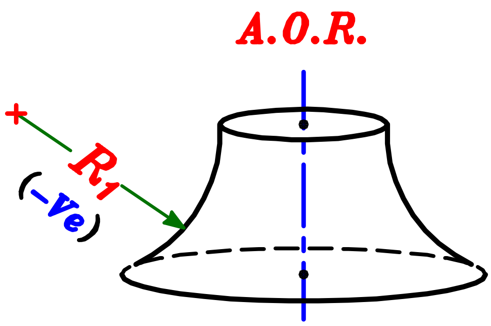
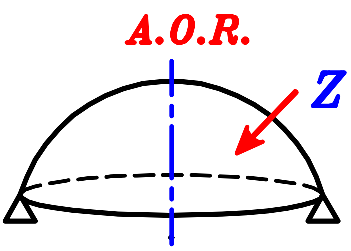
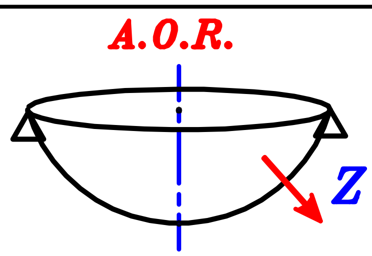


Z (−Ve) Sign

عندما تكون Z خارجه

بعيدا عن ال (A.O.R.)

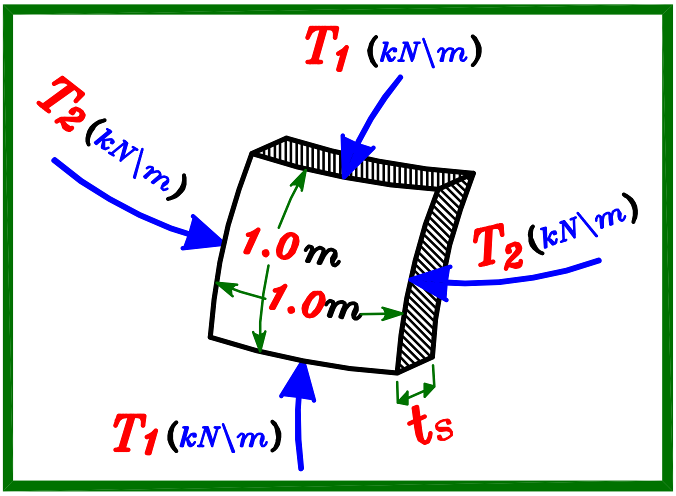
Parameter Signs.

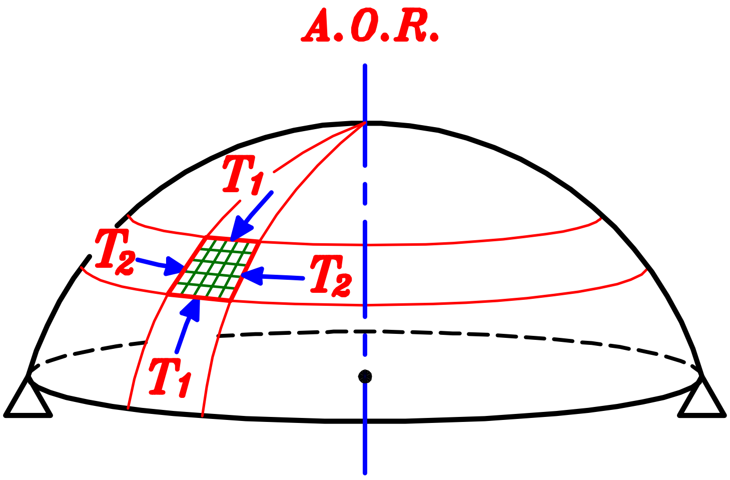
Parameter	(+Ve) Sign	(−Ve) Sign
T_1	Compression Force	Tension Force
T_2	Compression Force	Tension Force
W_ϕ	 W_ϕ داخلة الى ال Support	 W_ϕ خارجة من ال Support
r	(+Ve) دائماً	
ϕ	(+Ve) دائماً	
R_1	 عندما تكون خارجه بعيدا عن ال (A.O.R.)	 عندما تكون داخله فى اتجاه ال (A.O.R.)
R_2	(+Ve) دائماً	
Z	 عندما تكون Z داخله فى اتجاه ال (A.O.R.)	 عندما تكون Z خارجه بعيدا عن ال (A.O.R.)

Calculation of Internal Forces (T_1) & (T_2).

T_1 is **Meridian Force.** $(kN\backslash m)$

T_2 is **Ring Force.** $(kN\backslash m)$





$$\boxed{T_1 = \frac{W_\phi}{2\pi r \sin\phi}}$$

اثبات القانون فى صفحه 132

$$\boxed{\frac{T_1}{R_1} + \frac{T_2}{R_2} = Z}$$

اثبات القانون فى صفحه 133

ملحوظه هامه .

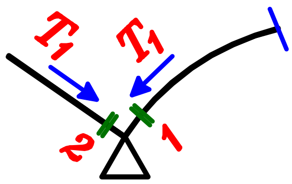
* تحديد اشاره (T_1) يعتمد على اشاره (W_ϕ) فقط

$$T_1 = \frac{\pm W_\phi}{2\pi r \sin\phi}$$

* تحديد اشاره (T_2) يعتمد على اشاره (T_1) و اشاره (R_1) و اشاره (Z)

$$\frac{\pm T_1}{\pm R_1} + \frac{T_2}{R_2} = \pm Z$$

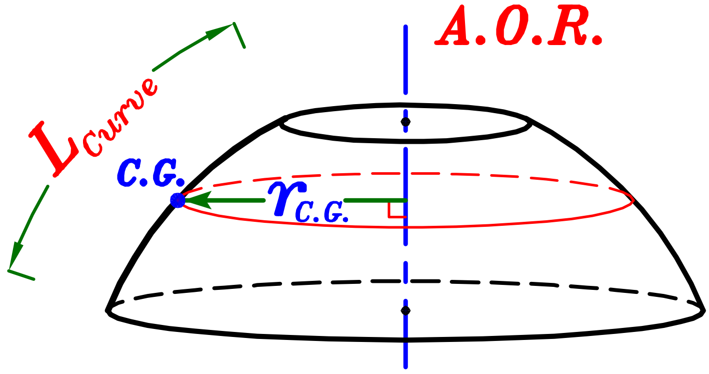
فى حاله وجود ركيزه تفصل بين سطحين يتم التعامل مع كل سطح على حده و لا يوجد بينهما أى أثر .

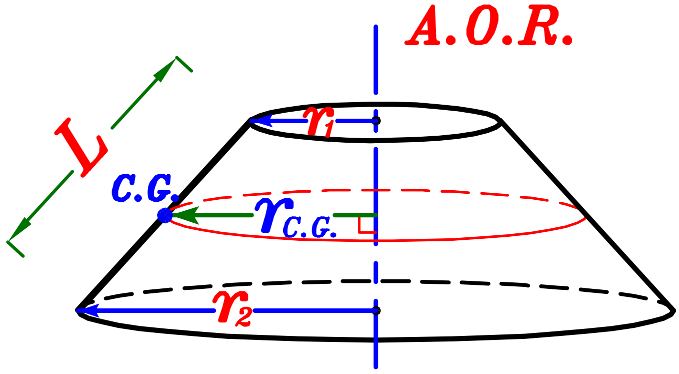


T_1, T_2 لـ Sec.① لا علاقه لها بـ T_1, T_2 لـ Sec.②

Theory of Surface Areas of S.O.R.

مساحه السطح الناتجه من دوران خط أو منحنى حول محور
تساوى طول الخط أو المنحنى مضروبا فى محيط الدائره الناتجه عن
دوران نقطه مركز ثقل (C.G.) هذا الخط أو المنحنى حول نفس المحور.



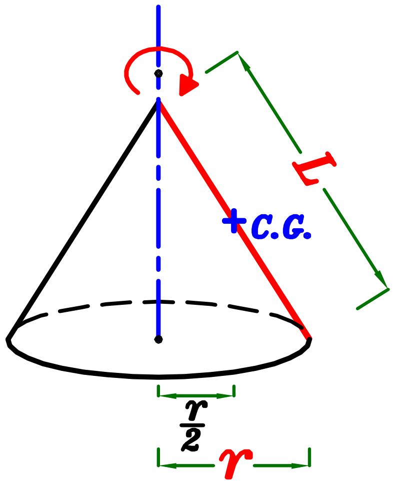


$$\boxed{r_{C.G.} = \frac{r_1 + r_2}{2}}$$

$$\boxed{S.A. = L_{Curve} * 2\pi * r_{C.G.}}$$

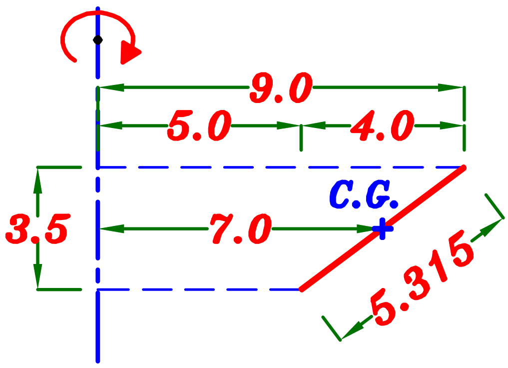
$$\boxed{S.A. = L * 2\pi * r_{C.G.}}$$

Example.



$$S.A. = L * 2\pi * r_{C.G.}$$

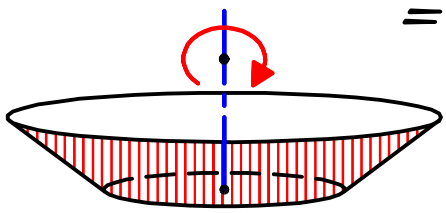
$$= L * 2\pi * \frac{r}{2} = \pi * r * L$$



$$S.A. = L * 2\pi * r_{C.G.}$$

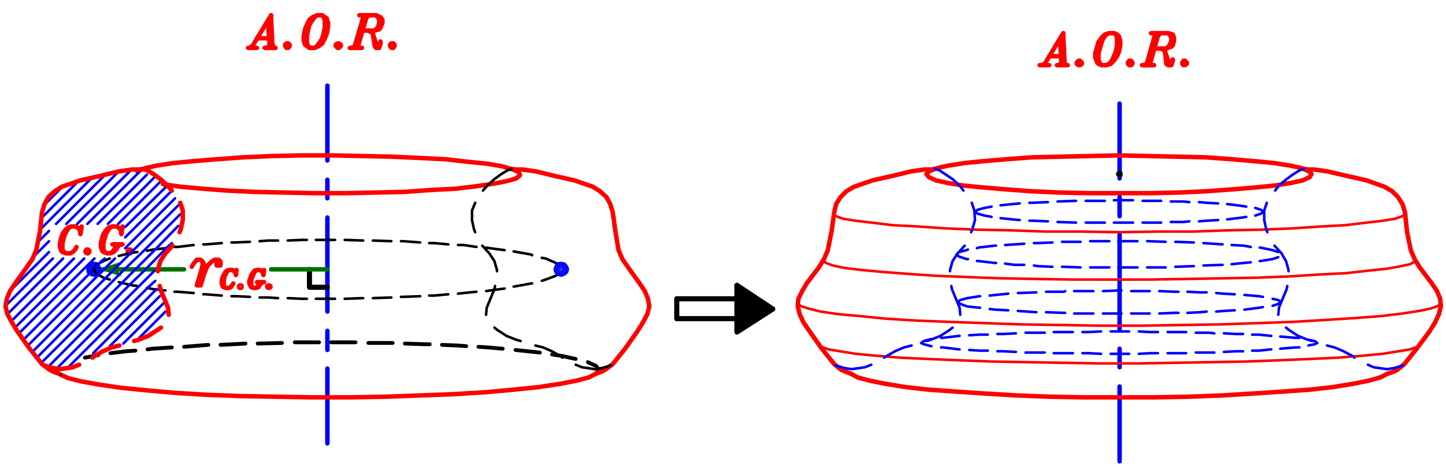
$$= 5.315 * 2\pi * 7.0$$

$$= 233.76\ m^2$$



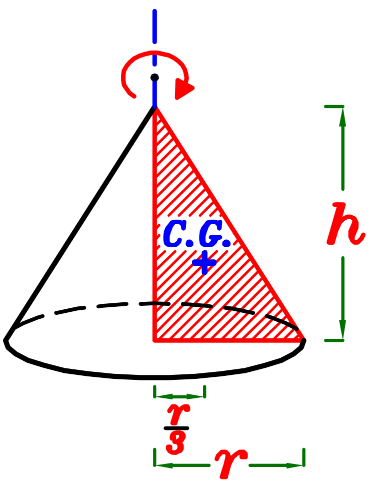
Theory of Volumes of S.O.R.

الحجم الناتج من دوران مساحه حول محور تساوى قيمه هذه المساحه مضروبا فى محيط الدائره الناتجه عن دوران نقطه مركز ثقل (C.G.) هذه المساحه حول نفس المحور .



$$\boxed{Volume = Area * 2\pi * r_{C.G.}}$$

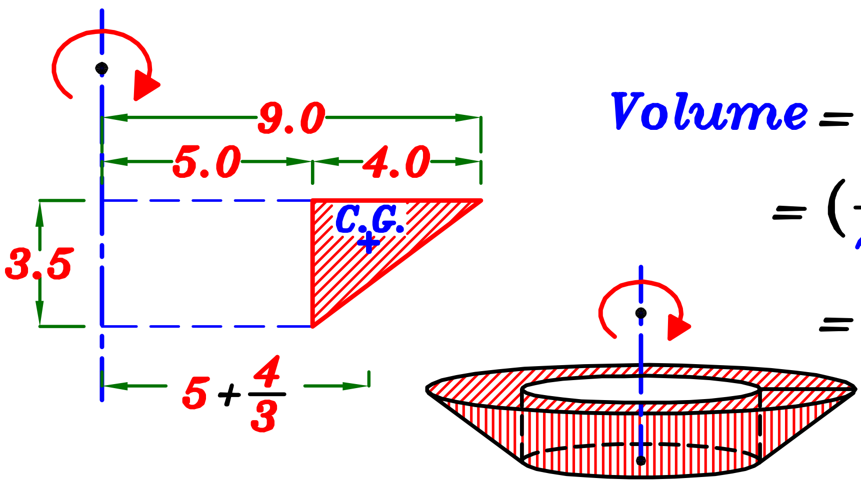
Example.



$$Volume = Area * 2\pi * r_{C.G.}$$

$$= \left(\frac{1}{2} * r * h\right) * 2\pi * \frac{r}{3}$$

$$= \frac{\pi * r^2 * h}{3}$$



$$Volume = Area * 2\pi * r_{C.G.}$$

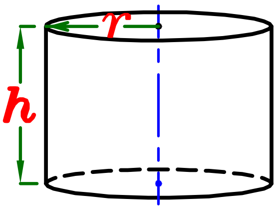
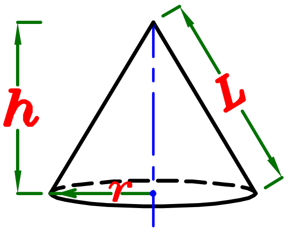
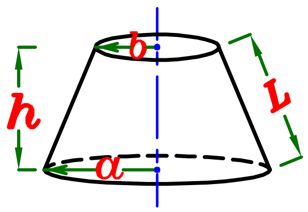
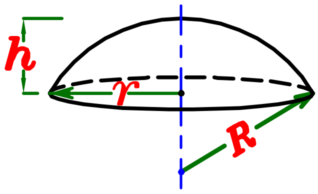
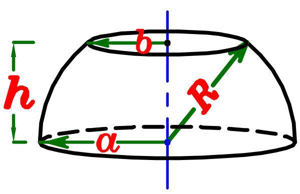
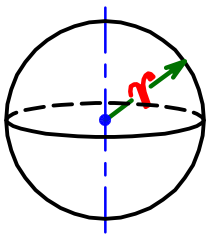
$$= \left(\frac{1}{2} * 3.5 * 4\right) * 2\pi * \left(5 + \frac{4}{3}\right)$$

$$= 278.55 \; m^3$$

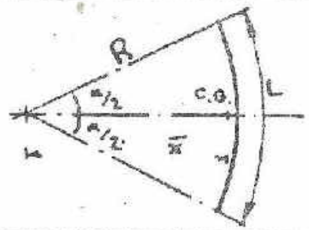
Volume and Surface Areas For some shapes.

Old tables Page 121

حفظ

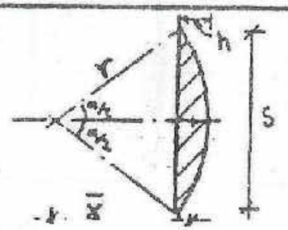
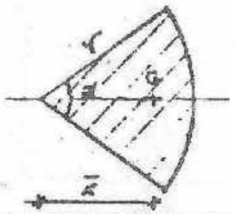
Name	Shape	Surface Area	Volume
Cylinder		$S.A. = 2\pi r * h$	$V = \pi r^2 * h$
Cone		$S.A. = \pi * L * r$	$V = \frac{1}{3} * \pi * r^2 * h$
Part Of Cone		$S.A. = \pi * L\,(a+b)$	$V = \frac{\pi h}{3}(a^2+b^2+ab)$
Dome		$S.A. = 2\pi * R * h$	$V = \pi * h^2 (R - \frac{h}{3})$
Part Of Dome		$S.A. = 2\pi * R * h$	$V = \frac{\pi h}{6}(3a^2+3b^2+h^2)$
Sphere		$S.A. = 4 * \pi * r^2$	$V = \frac{4}{3} * \pi * r^3$

Arc of a Circle

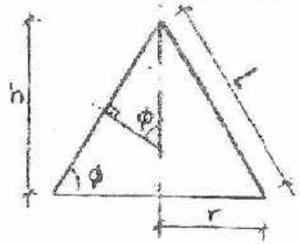
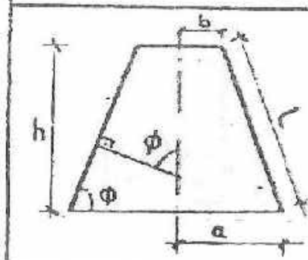
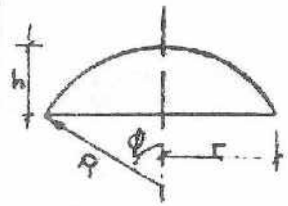
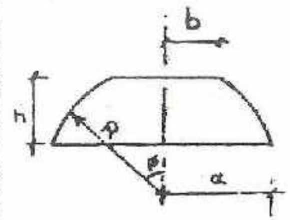


$\bar{X} = R \sin(a/2) \;/\; (a/2)$
$L = r \cdot a$

Segment and Sector of a Circle

Shape	Area	C.G. ($\bar{X}$)
	$r^2\ a/2$ $-\ s(r-h)/2$	$s^3/(12\ A)$
	$r^2\ a\ /\ 2$	$\dfrac{2\ r\ \sin\ (a/2)}{(3a/2)}$

Solid Bodies

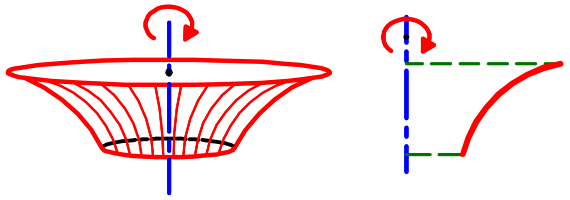
Shape	Volume	Surface Area
	CONE $\pi\ r^2\ h\ /\ 3$	$\pi\ r\ l$
	PART OF CONE $\dfrac{\pi\ h\ (a^2+b^2+ab)}{3}$	$\pi\ l\ (a+b)$
	DOME $\pi\ h^2\ (R-h/3) =$ $\pi\ h\ (3r^2+h^2)/6$	$2\ \pi\ R\ h =$ $\pi\ (r^2+h^2)$
	PART OF DOME $\dfrac{\pi\ h\ (3a^2+3b^2+h^2)}{6}$	$2\ \pi\ R\ h$

<u>For Surfaces of Revolution</u> :

* Meridian Force = T_1
$T_1 = W\phi\ /\ 2\ \pi\ r\ \sin(\phi)$

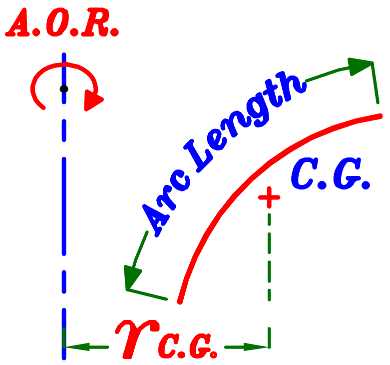
* Ring Force = T_2
$T_1/R_1 + T_2/R_2 = Z$

Special Cases.

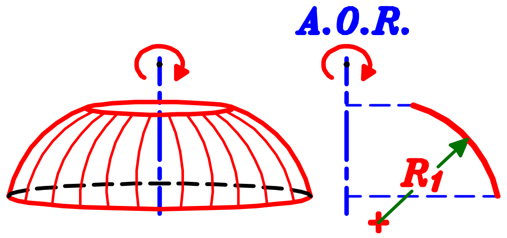


اذا كان المنحنى للخارج (كما بالشكل)

فانه يجب لحساب الـ Surface Area استخدام القانون :

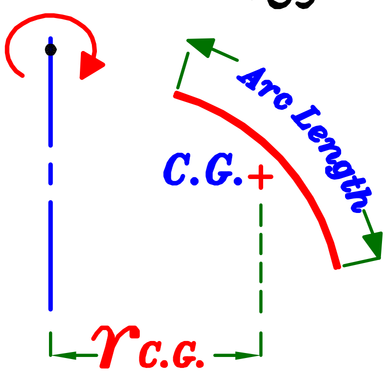


$$\boxed{S.A. = \text{Arc Length} * 2\pi * r_{C.G.}}$$



اذا كان المنحنى للداخل لكن مركزه ليس على الـ A.O.R.

فانه يجب لحساب الـ Surface Area استخدام القانون :



$$\boxed{S.A. = \text{Arc Length} * 2\pi * r_{C.G.}}$$

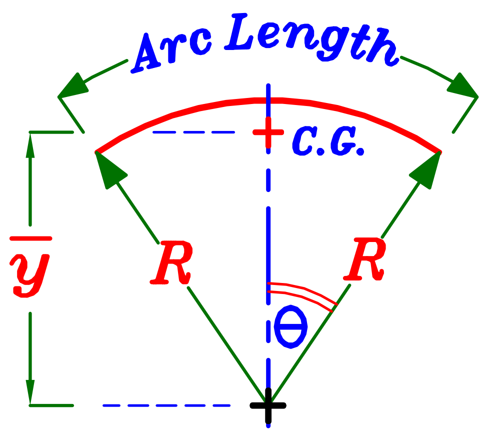
لاى قوس فى دائره .

Radian

$$\boxed{\text{Arc Length} = 2 * R * \theta}$$

$$\boxed{\bar{y} = \frac{R * \sin\theta}{\theta}}$$

Radian



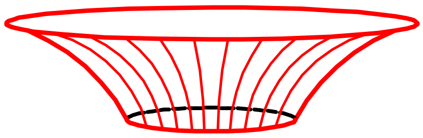
where: θ is the Central Angle.

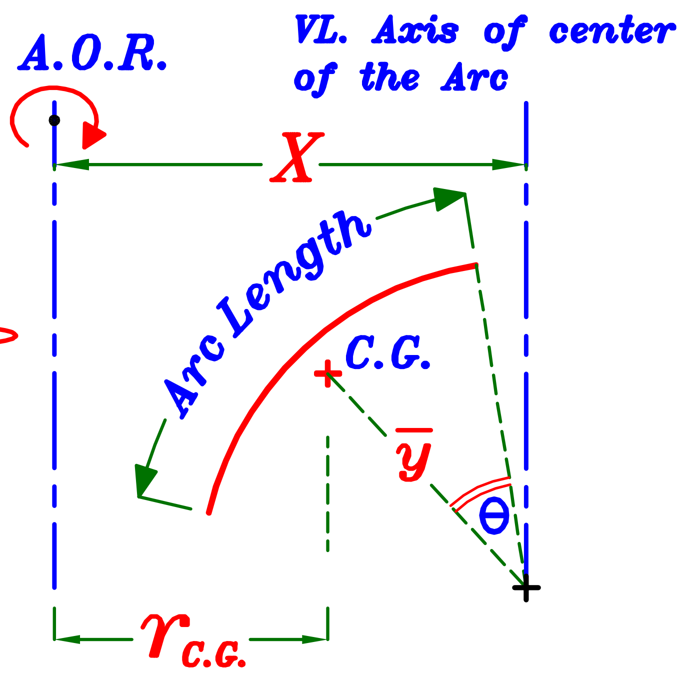
R is the Radius of the Arc.

$$\boxed{S.A. = \text{Arc Length} * 2\pi * r_{c.G.}}$$

$$\boxed{\text{Arc Length} = 2 * R * \theta}$$

$$\boxed{\bar{y} = \frac{R * \sin\theta}{\theta}}$$





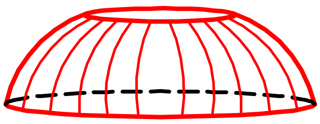
X is the HL. distance between the Axis of Revolution and the VL. Axis of center of the Arc.

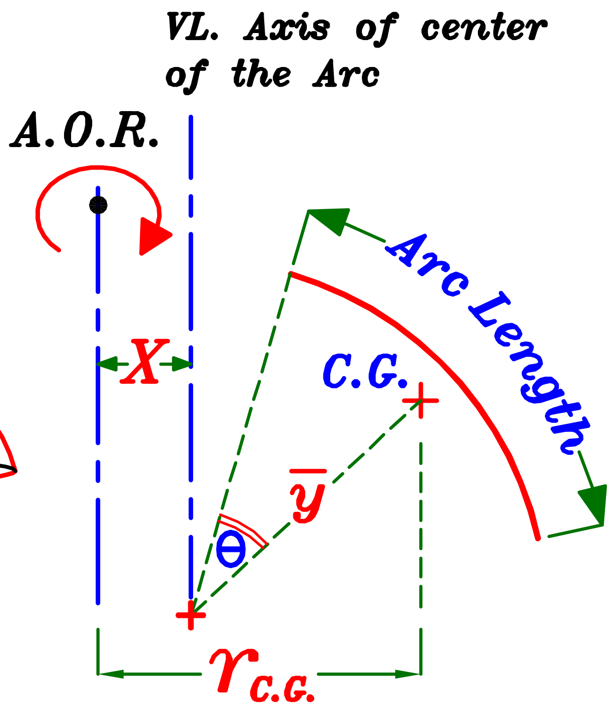
المنحنى للداخل لكن مركزه ليس على الـ A.O.R.

$$\boxed{S.A. = \text{Arc Length} * 2\pi * r_{c.G.}}$$

$$\boxed{\text{Arc Length} = 2 * R * \theta}$$

$$\boxed{\bar{y} = \frac{R * \sin\theta}{\theta}}$$





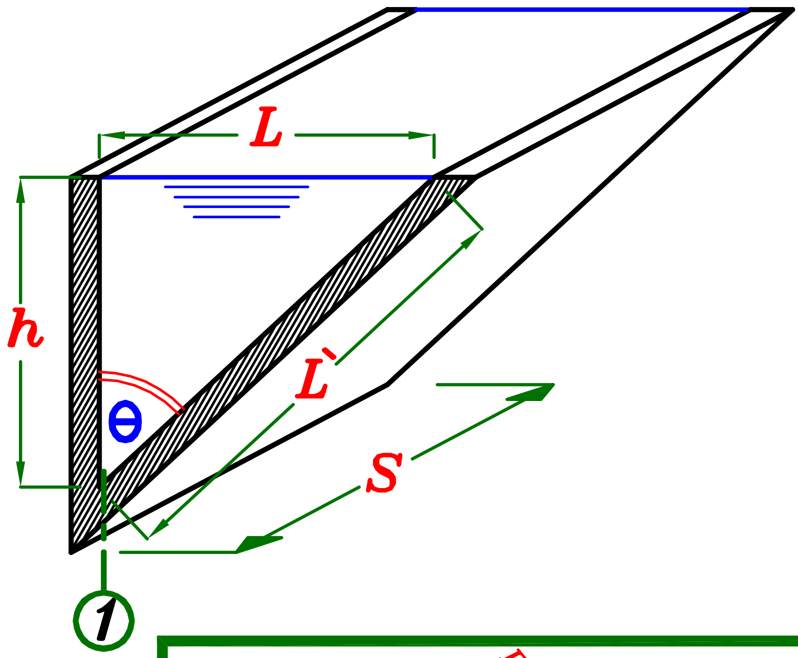
X is the HL. distance between the Axis of Revolution and the VL. Axis of center of the Arc.

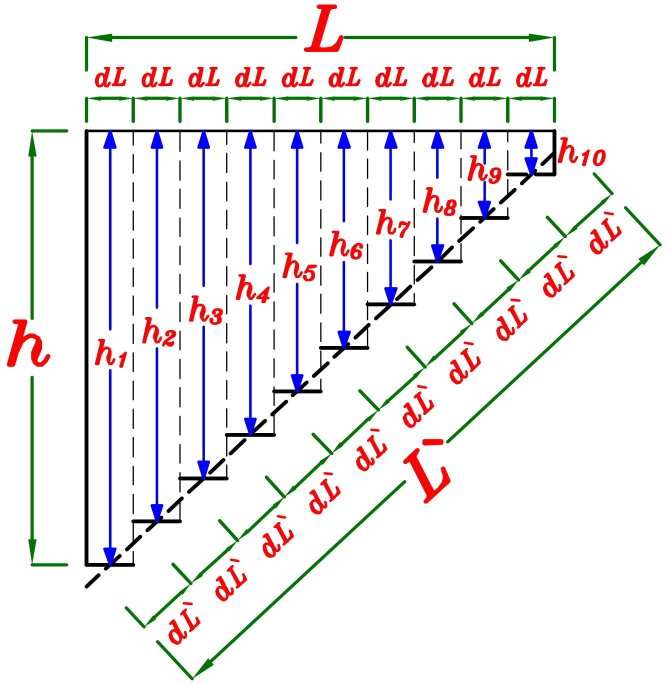
سيتم شرح هذا الجزء بالتفصيل و الامثله لاحقاً

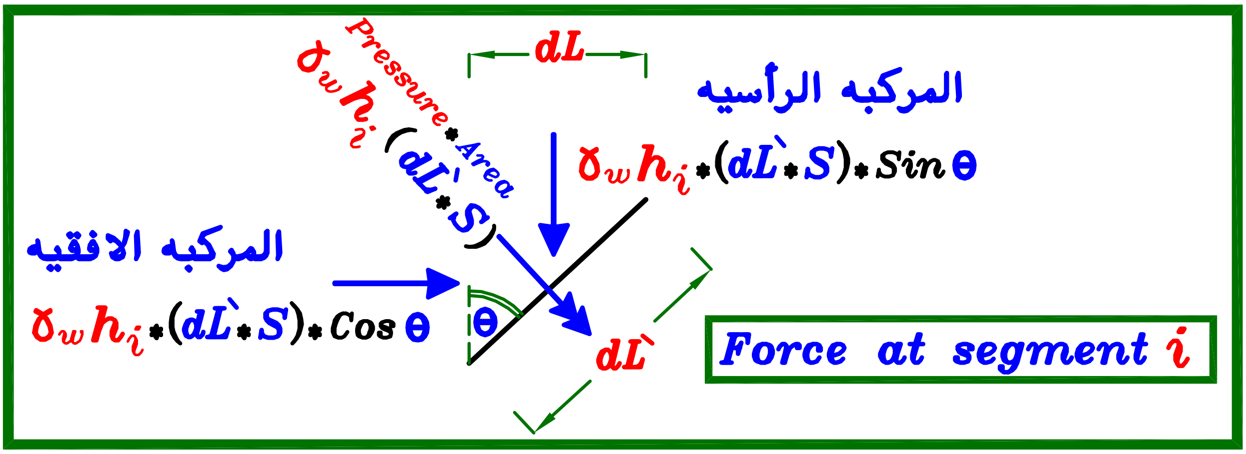
Water pressure effect.

السطح مائل للخارج أى ان الماء تضغط على السطح من أعلى .

Calculate W_ϕ For section ① due to water pressure only.







محصله قوى الضغط العموديه على السطح فى طول $dL`$ =

$$Pressure * Area = \gamma_w h_i * (dL` * S)$$

اتجاهها لاسفل ↘

المركبه الرأسيه لقوى الضغط فى طول dL للجزء i = اتجاهها لاسفل ↓

$$= \gamma_w h_i * (dL` * S) * \sin\theta = \gamma_w h_i * (dL` * S) * \frac{dL}{dL`} = \gamma_w h_i * (dL * S)$$

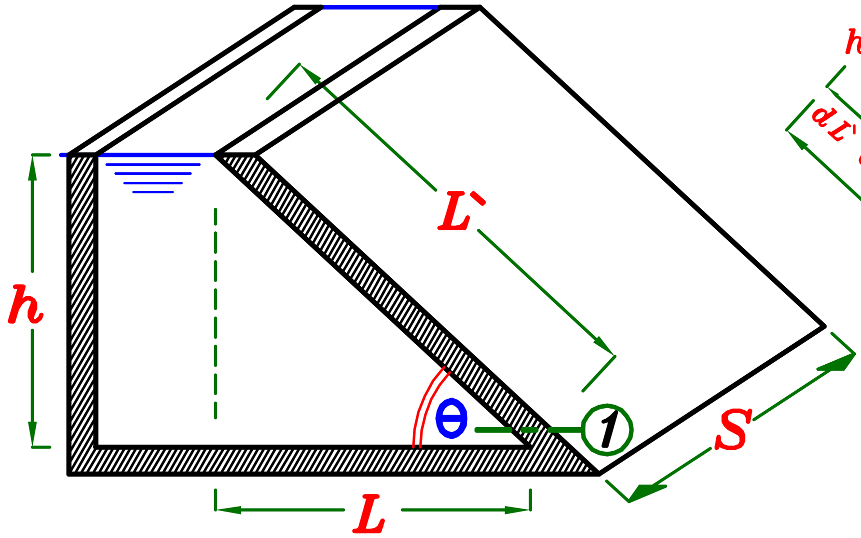
محصله المركبه الرأسيه لقوى الضغط فى طول L = W_ϕ اتجاهها لاسفل ↓

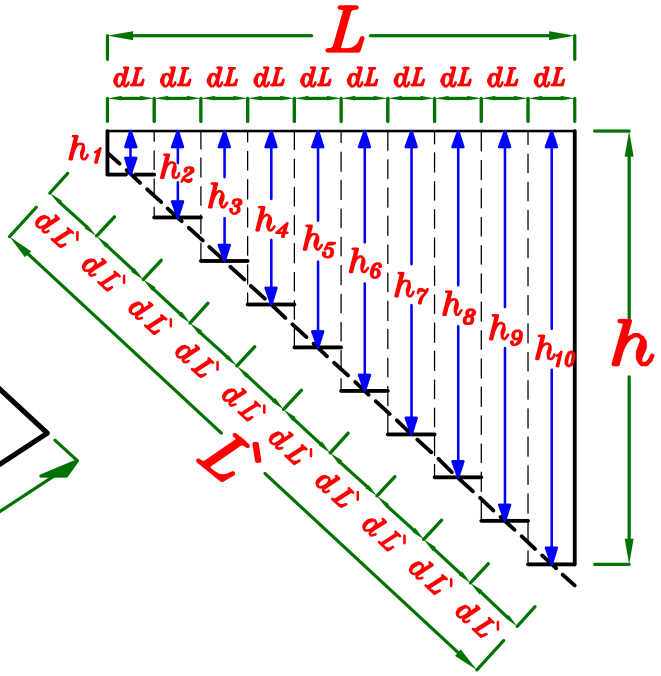
$$W_\phi = \gamma_w * (\sum h_i * dL) * S = \gamma_w * \sum Area * S = \gamma_w * \text{Water Volume}$$

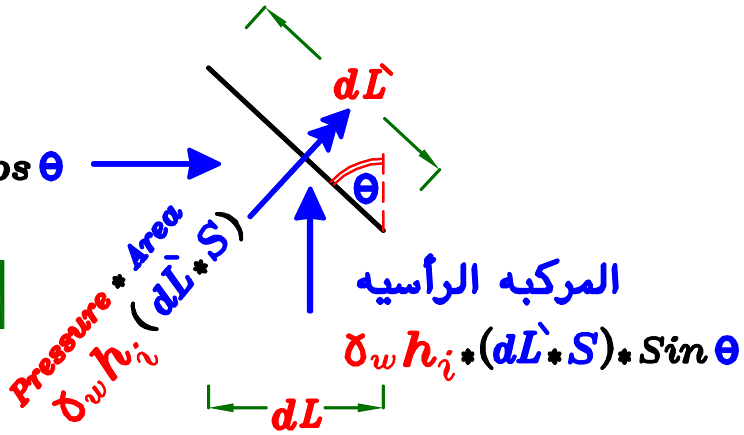
$$\boxed{W_\phi = \gamma_w * \text{Volume of water above the surface.} \downarrow}$$

السطح مائل للداخل أى ان الماء تضغط على السطح من أسفل .

Calculate W_ϕ For section ①
due to water pressure only.







محصله قوى الضغط العموديه على السطح فى طول $dL`$ =

$$Pressure * Area = \gamma_w h_i * (dL` * S)$$ اتجاهه لاعلى ↗

المركبه الرأسيه لقوى الضغط فى طول dL للجزء i = اتجاهه لاعلى ↑

$$= \gamma_w h_i * (dL` * S) * Sin\,\theta = \gamma_w h_i * (dL` * S) * \frac{dL}{dL`} = \gamma_w h_i * (dL * S)$$

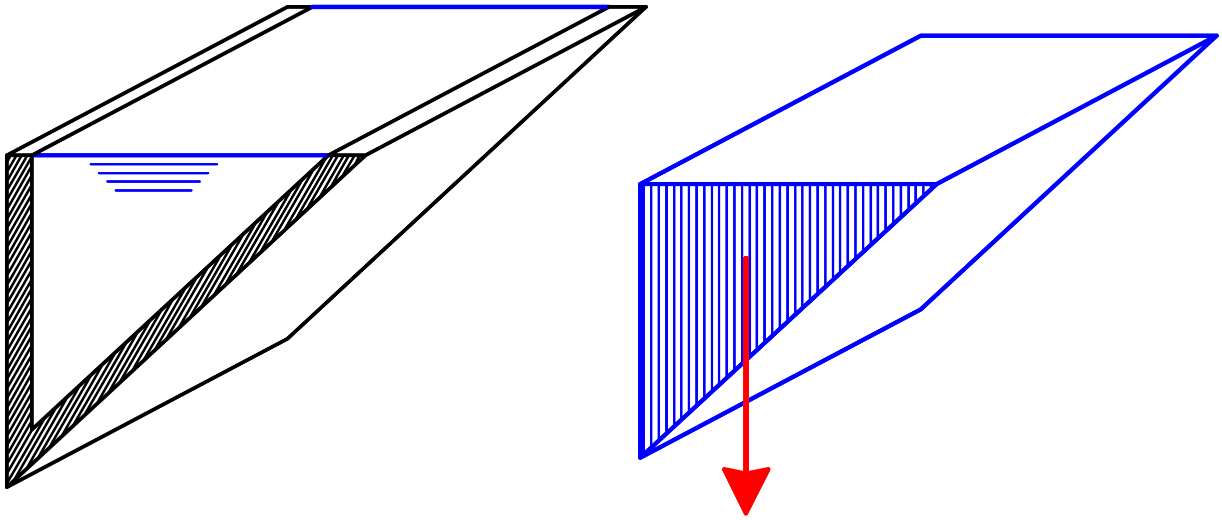
محصله المركبه الرأسيه لقوى الضغط فى طول L = W_ϕ اتجاهه لاعلى ↑

$$W_\phi = \gamma_w * (\sum h_i * dL) * S = \gamma_w * \sum Area * S = \gamma_w * Water\ Volume$$

$$\boxed{W_\phi = \gamma_w * \text{Virtual Volume of water above the surface.} \uparrow}$$

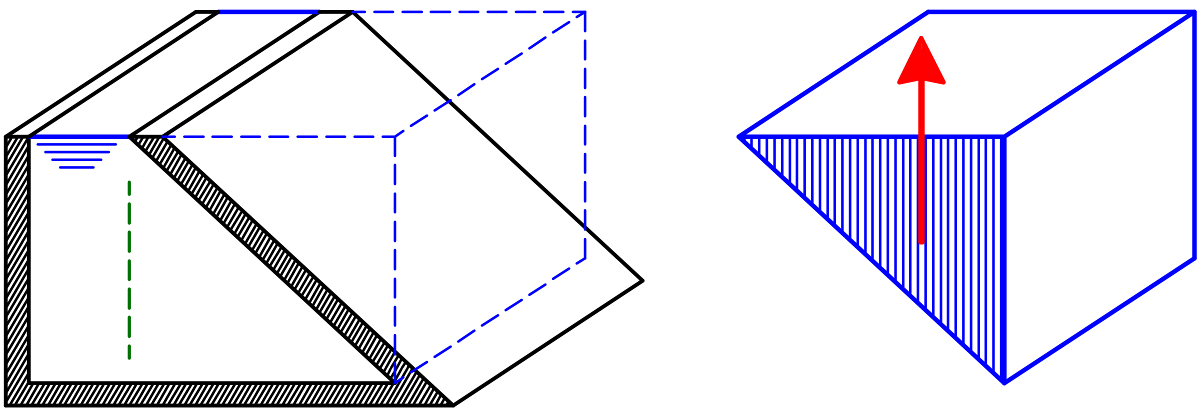
يساوى الحجم الوهمى للماء فوق السطح مباشره حتى منسوب سطح الماء .

اذا كانت المياه موجوده اعلى السطح ستضغط على السطح الى اسفل



$$W\phi_{water} = \gamma_w * \text{Volume of water above the surface.} \downarrow$$

اذا كانت المياه موجوده اسفل السطح ستضغط على السطح الى اعلى .

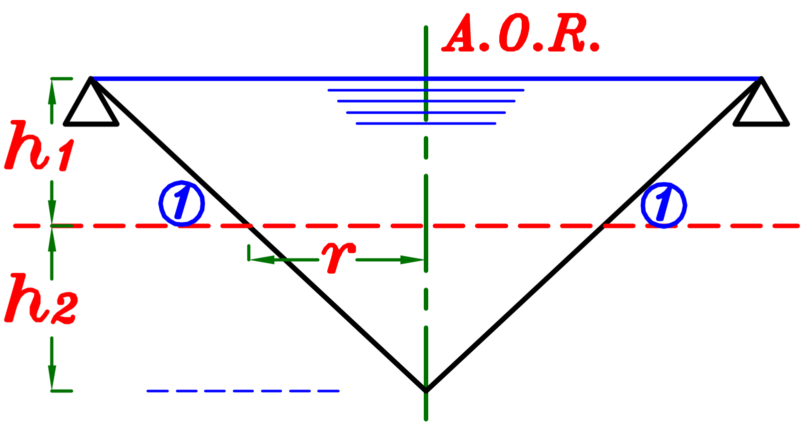


$$W\phi_{water} = \gamma_w * \text{Virtual Volume of water above the surface.} \uparrow$$

يساوى الحجم الوهمى للماء فوق السطح مباشره حتى منسوب سطح الماء .

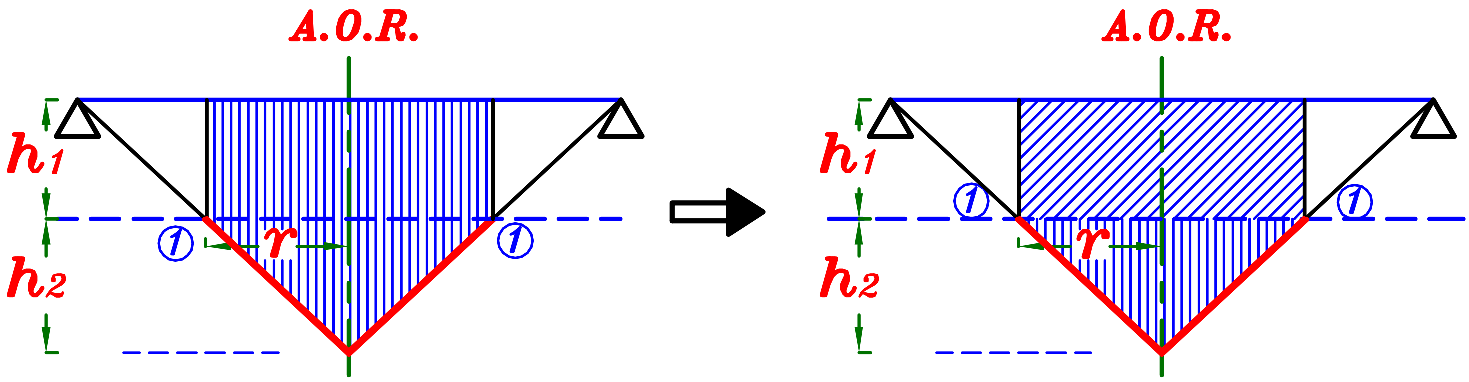
Example.

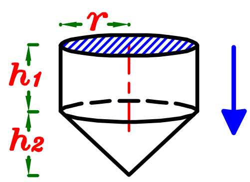
Calculate (W_ϕ & Z) For section ① due to water pressure only.

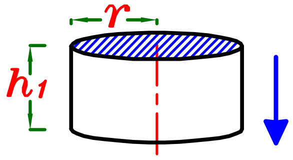
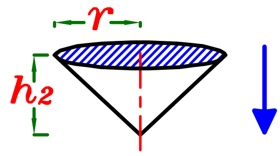


W_ϕ

عند Sec. ① سيكون ضغط الماء بعيدا عن ال **support** كله لاسفل .



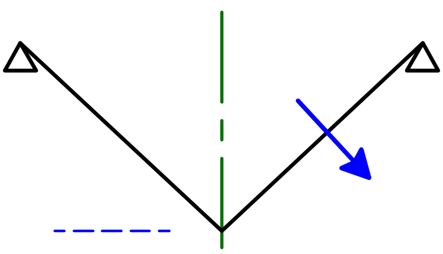
$W_\phi = \gamma_w *$ [Volume of ]

$\therefore W_\phi = \gamma_w *$ [Volume of  + ]

$\boxed{\gamma_w = 10\ kN/m^3}$

اشاره W_ϕ $(-Ve)$ لان اتجاهها خارج من ال Support

Z

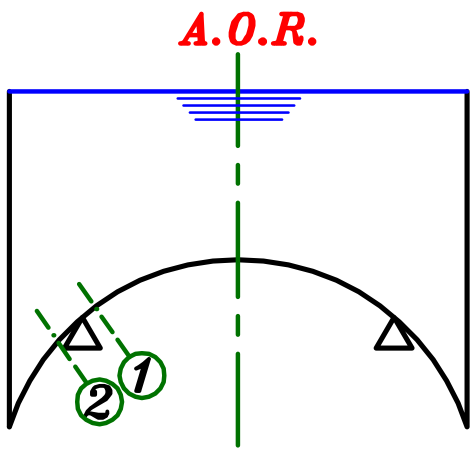


عند Sec. ① $\boxed{Z = \gamma_w * h_1}$

اشاره Z $(-Ve)$ لان اتجاهها خارج من المحور

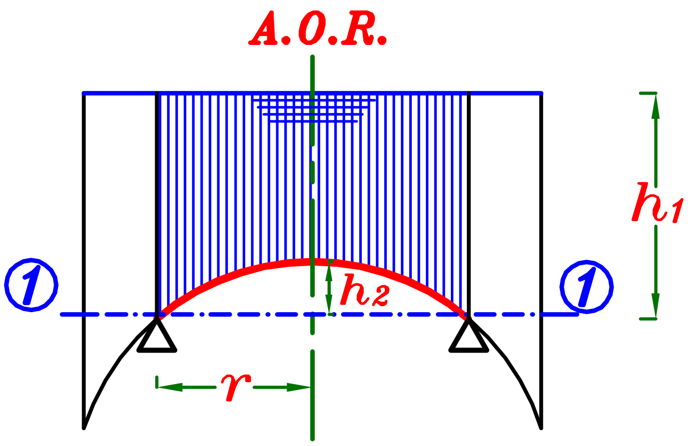
Example.

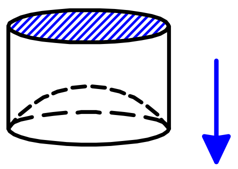
Calculate $(W_\phi \,\&\, Z)$ For sections ①, ② due to water pressure only.

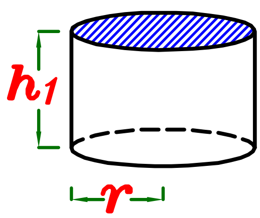
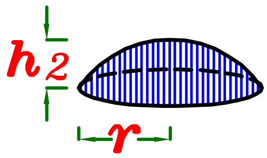


Sec. ①

عند Sec. ① أعلى الـ support
سيكون ضغط الماء بعيدا عن الـ support كله لاسفل .



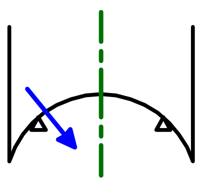
$W_\phi = \gamma_w * \Big[$ Volume of  $\Big]$

$W_\phi = \gamma_w * \Big[$ Volume of  $-$  $\Big]$

$\boxed{\gamma_w = 10 \; kN/m^3}$

اشاره W_ϕ (+Ve) لان اتجاهها داخل الى الـ Support

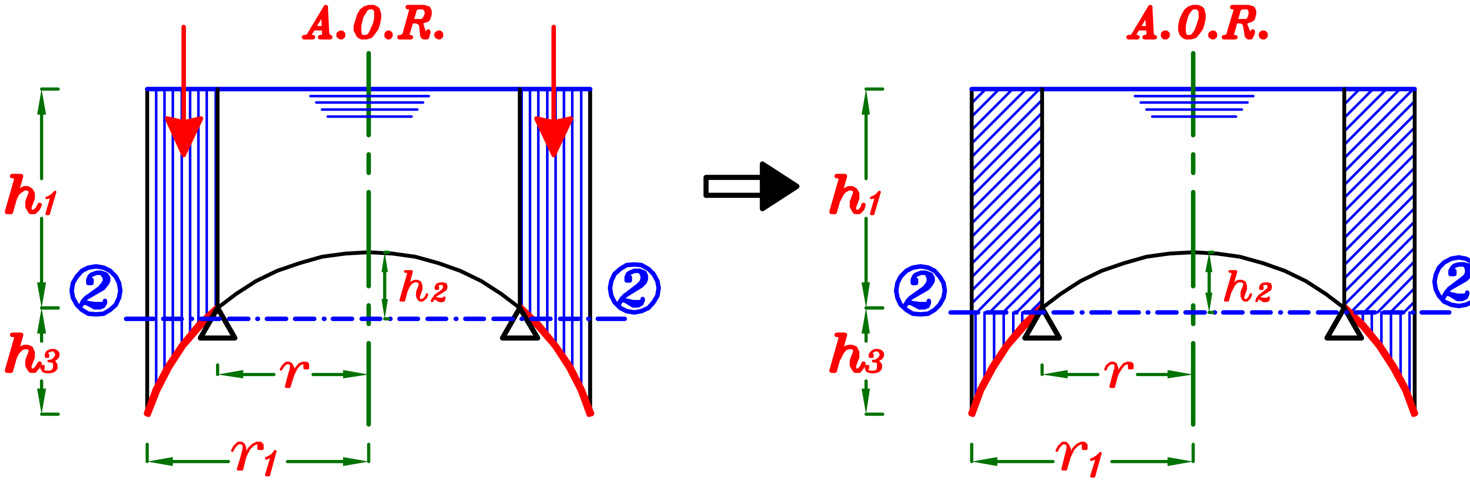
اشاره Z (+Ve)
لان اتجاهها داخل الى المحور

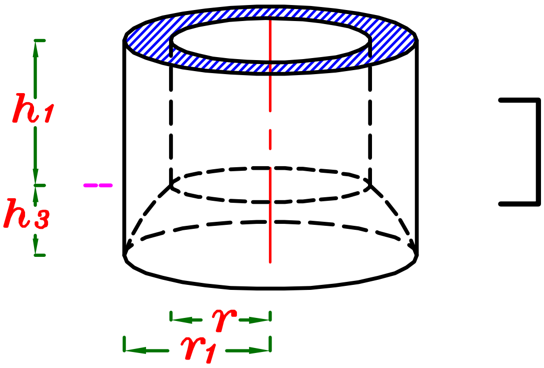


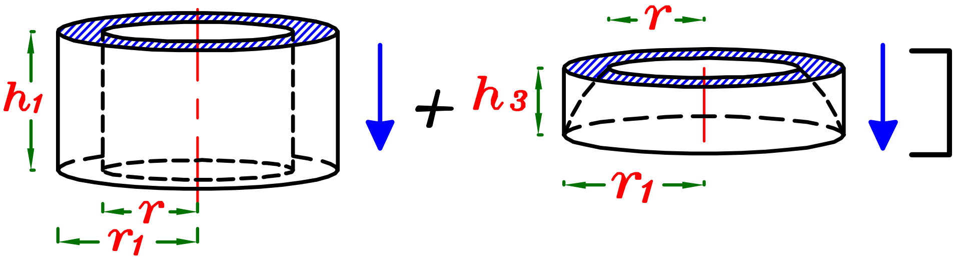
عند Sec. ① $\boxed{Z = \gamma_w * h_1}$

Sec. ②

عند Sec. ② أسفل ال support
سيكون ضغط الماء بعيدا عن ال support كله لاسفل .



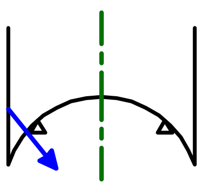
$W_{\phi} = \gamma_w * \Big[$ Volume of  $\Big]$

$W_{\phi} = \gamma_w * \Big[$ Volume of  $\Big]$

$\boxed{\gamma_w = 10\ kN/m^3}$

اشاره W_{ϕ} $(-Ve)$ لان اتجاهها خارج من ال Support

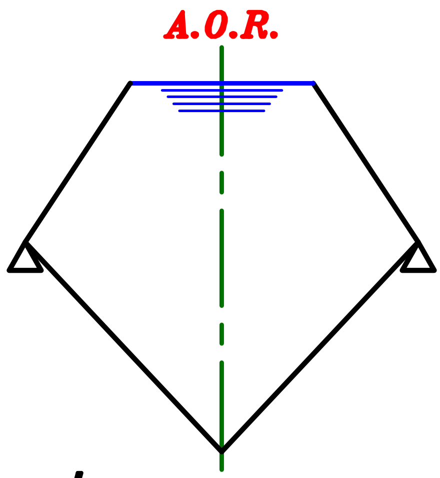
عند Sec. ② $\boxed{Z = \gamma_w * h_1}$



اشاره Z $(+Ve)$
لان اتجاهها داخل الى المحور

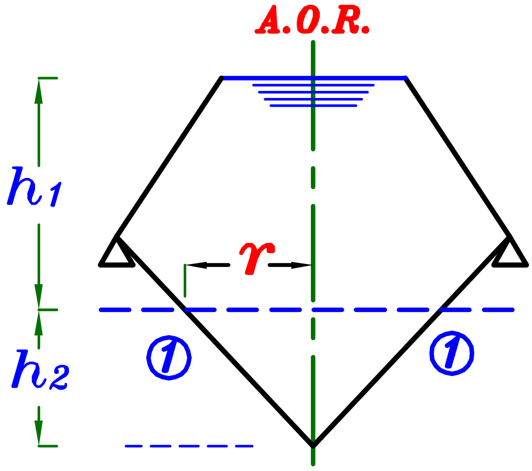
Example.

Calculate $(W_\phi \,\&\, Z)$ For sections above & under the supports due to water pressure only.

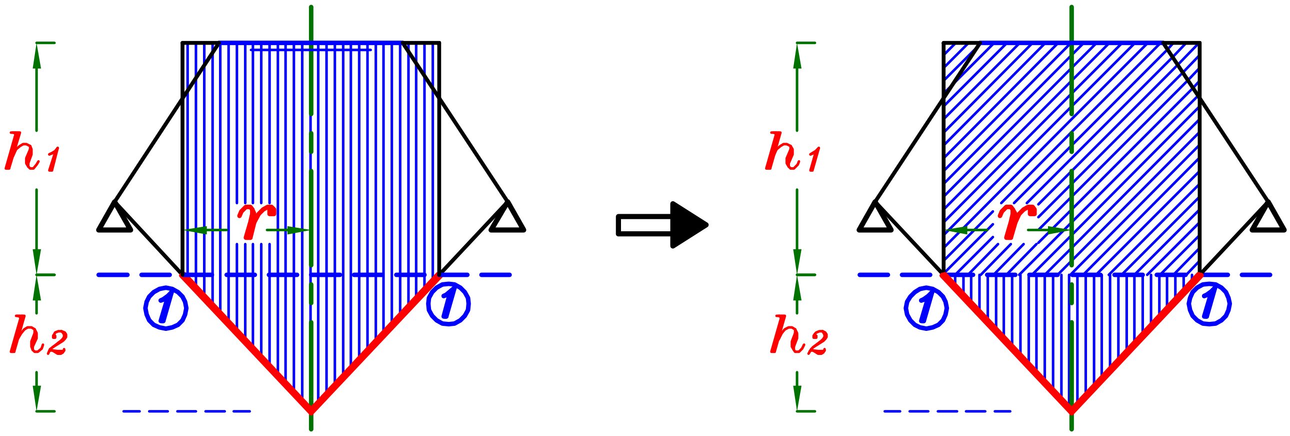


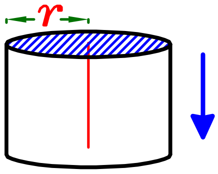
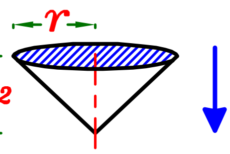
1– For section under the support.

W_ϕ



عند Sec. ① سيكون ضغط الماء
بعيدا عن ال support كله لاسفل .

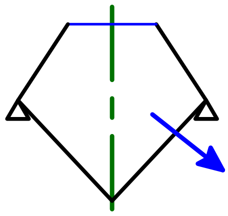


$\therefore W_\phi = \gamma_w * \Big[$ Volume of h_1  $+$ h_2  $\Big]$

$\boxed{\gamma_w = 10\ kN/m^3}$

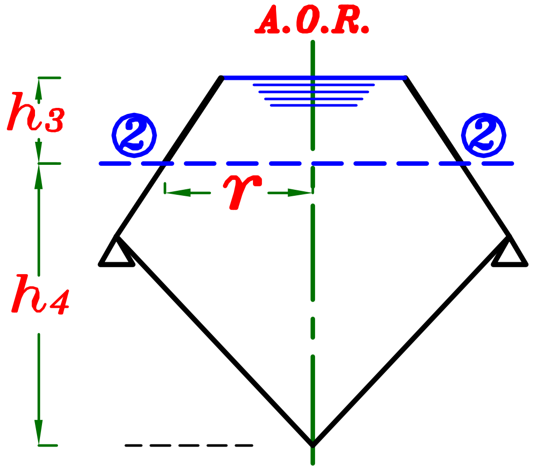
اشاره W_ϕ $(-Ve)$ لان اتجاهها خارج من ال Support

اشاره Z $(-Ve)$
لان اتجاهها خارج من المحور



عند Sec. ① $\boxed{Z = \gamma_w * h_1}$

2- For section above the support.

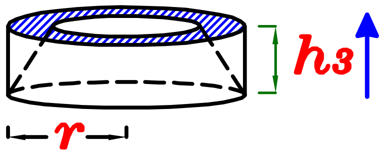


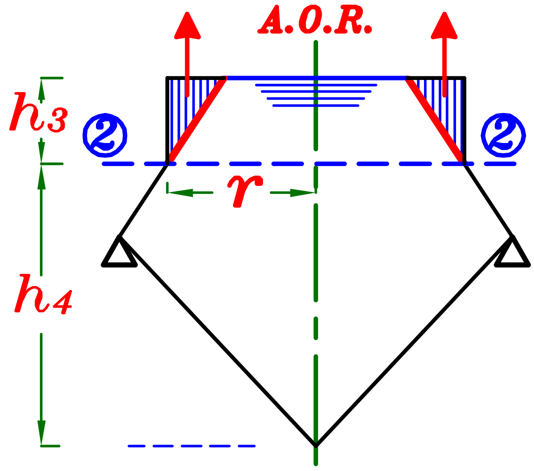
W_ϕ

عند $Sec.$ ② سيكون ضغط الماء

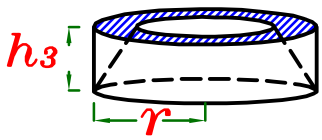
بعيدا عن الـ support كله لاعلى .

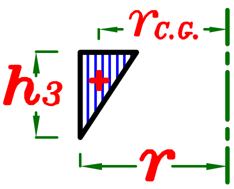
الحجم الوهمى للماء فوق السطح مباشره حتى منسوب سطح الماء .

$W_\phi = \gamma_w * $ Volume of 



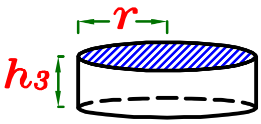
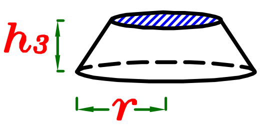
اشاره W_ϕ (-Ve) لان اتجاهها خارج من الـ Support

لحساب حجم  توجد طريقتين :

اما بطريقه 

$$\text{Volume} = \text{Area} * 2\pi * r_{c.G.}$$

او بطرح حجم اسطوانه ـ مخروط ناقص

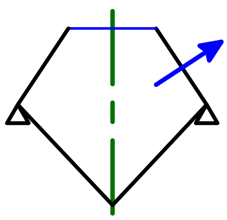
[Volume of  − ]

Z

عند $Sec.$ ② $\quad Z = \gamma_w * h_3$

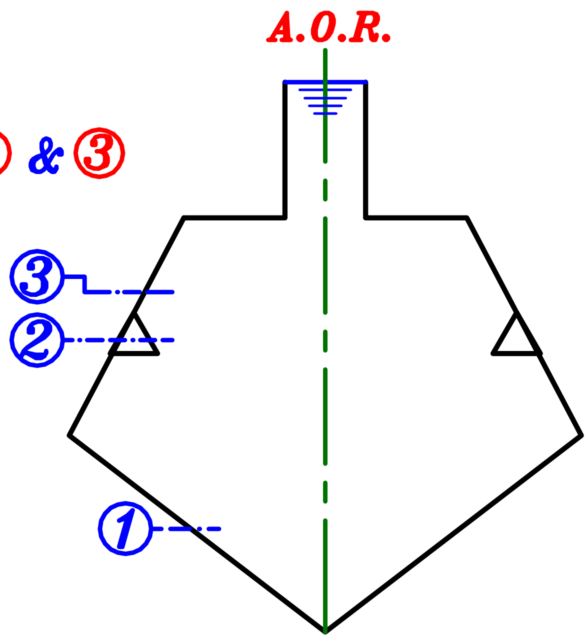
اشاره Z (-Ve)

لان اتجاهها خارج من المحور



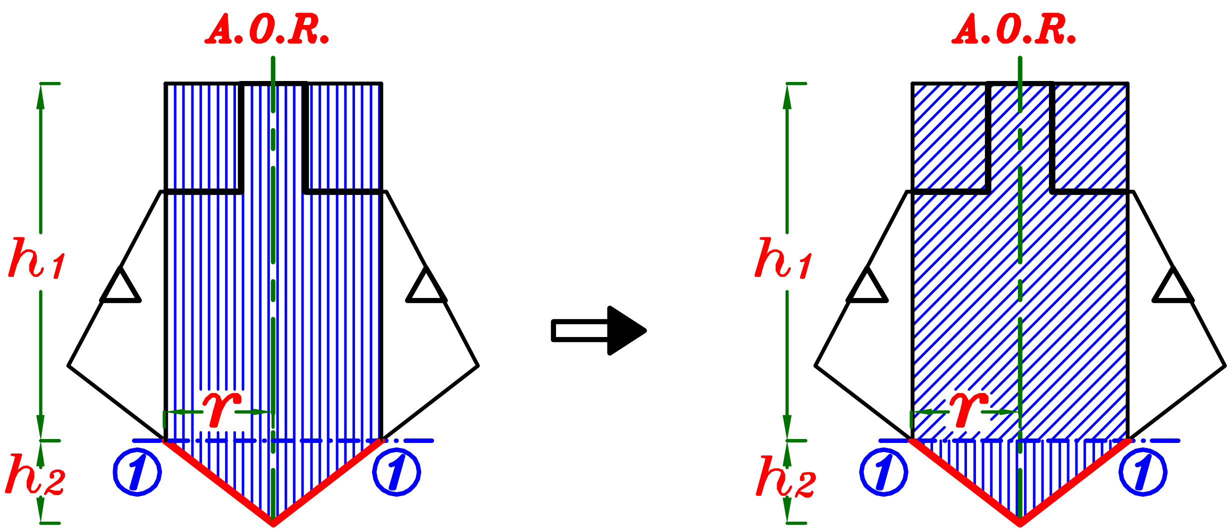
Example.

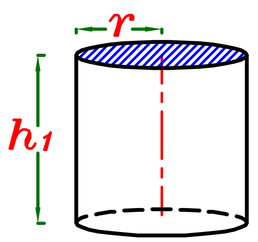
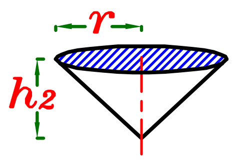
Calculate (W_ϕ & Z) For sections ①, ② & ③ due to water pressure only.



Sec. ①

عند Sec. ① سيكون ضغط الماء بعيدا عن ال support كله لاسفل .

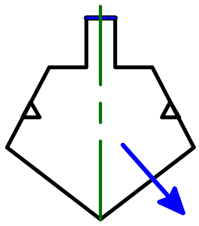


$\therefore W_\phi = \gamma_w *$ [Volume of  $\downarrow$ +  $\downarrow$]

$\boxed{\gamma_w = 10\ kN/m^3}$

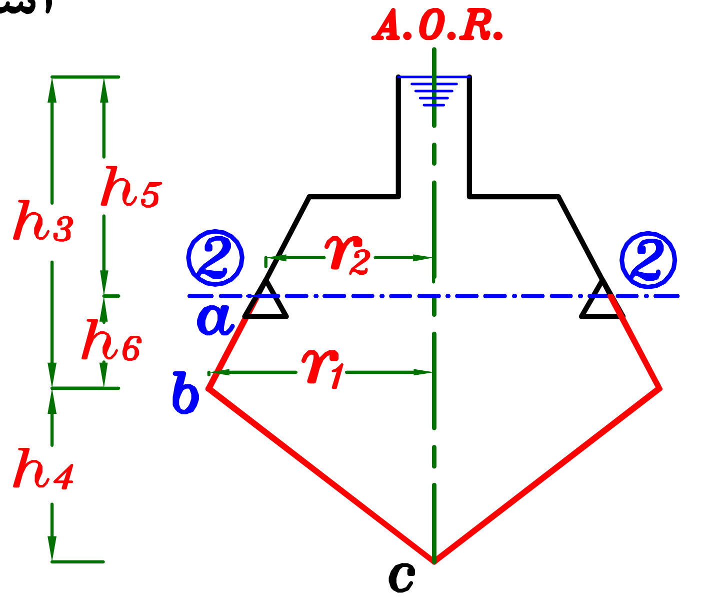
اشاره W_ϕ $(-Ve)$ لان اتجاهها خارج من ال Support

عند Sec. ① $\boxed{Z = \gamma_w * h_1}$

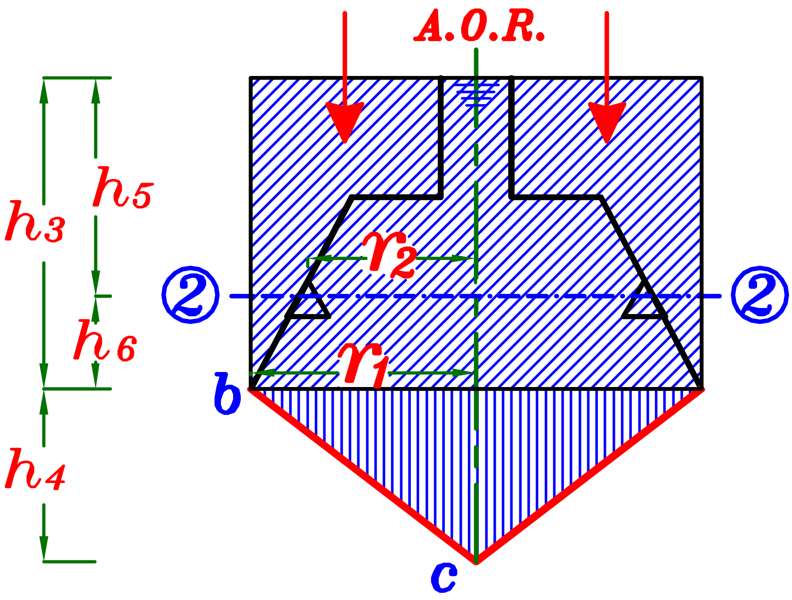


اشاره Z $(-Ve)$
لان اتجاهها خارج من المحور

Sec. ② أسفل ال support

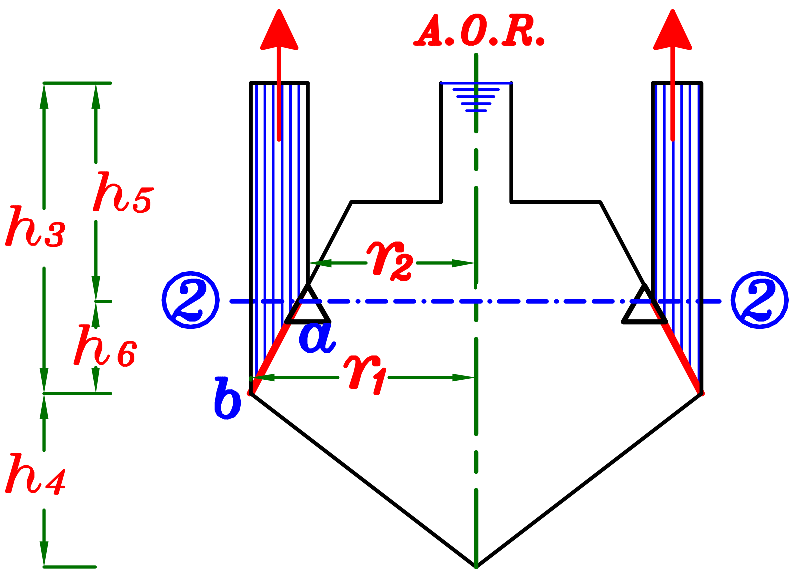


عند Sec. ② سيكون ضغط الماء بعيدا عن ال support لاسفل عند السطح b c
و سيكون لاعلى عند السطح b a



سيكون ضغط الماء لاسفل

عند السطح b c

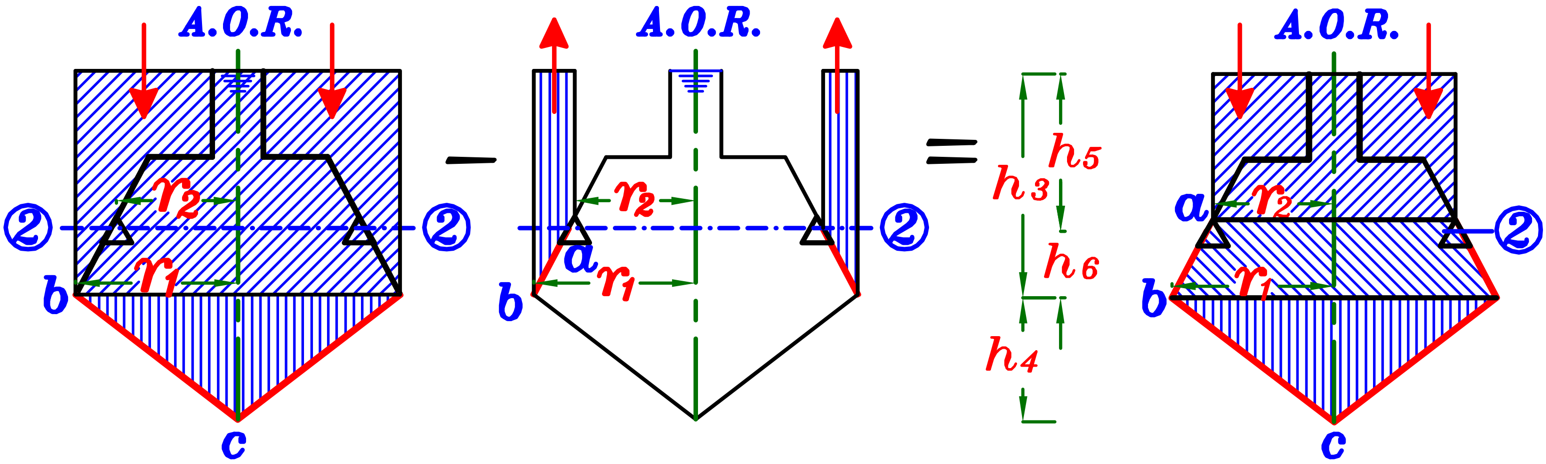


سيكون ضغط الماء لاعلى

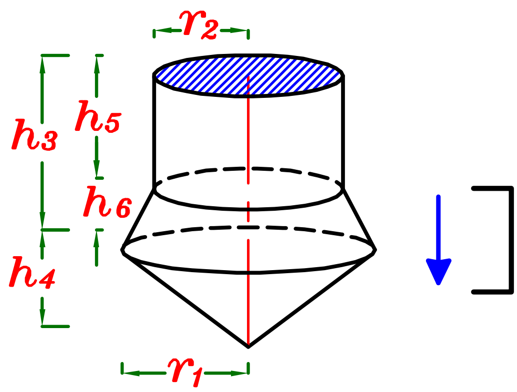
عند السطح b a

محصله ضغط المياه عند Sec. ② بعيدا عن ال support ستكون لاسفل

ستكون ضغط المياه على السطح bc لاسفل مطروحا منه ضغط المياه على السطح ab لاعلى

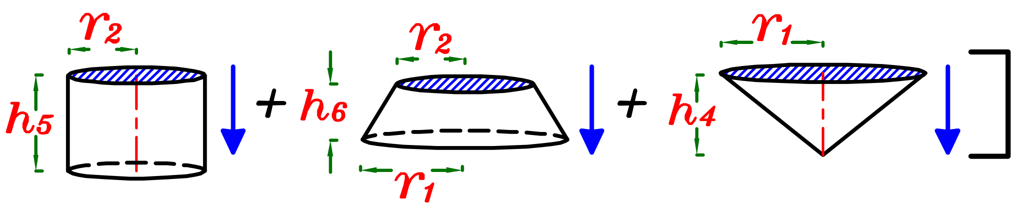


$W_\phi = \gamma_w *$ [Volume of



]

$W_\phi = \gamma_w *$ [Volume of h_5

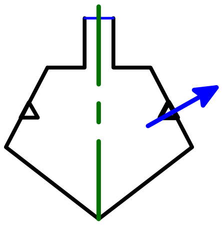


]

$\boxed{\gamma_w = 10\ kN/m^3}$

$\boxed{\text{اشاره } W_\phi\ (-Ve) \text{ لان اتجاهها خارج من ال Support}}$

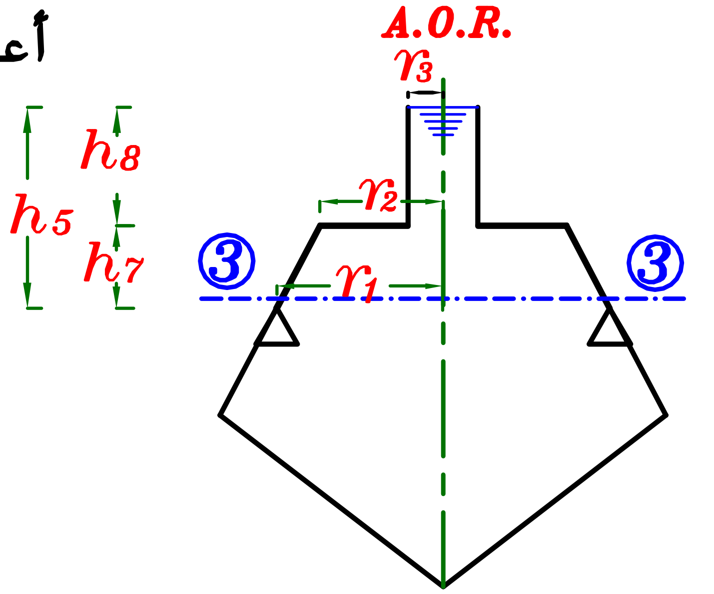
عند Sec. ② $\boxed{Z = \gamma_w * h_5}$



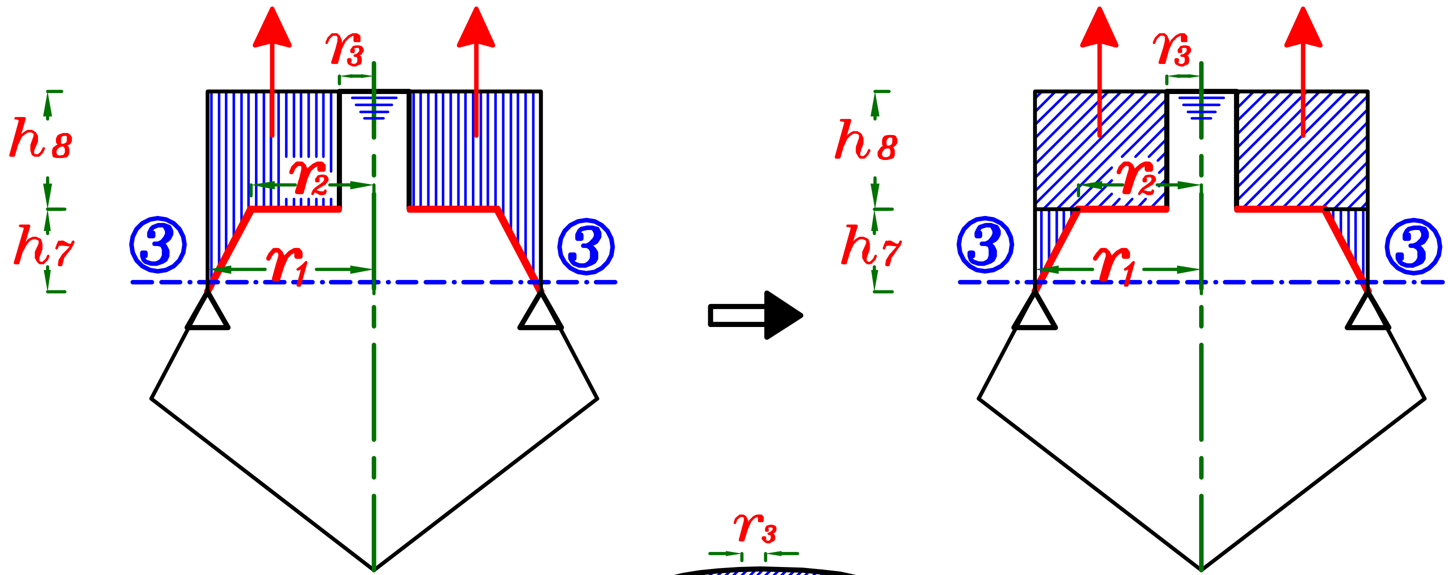
اشاره Z $(-Ve)$

لان اتجاهها خارج من المحور

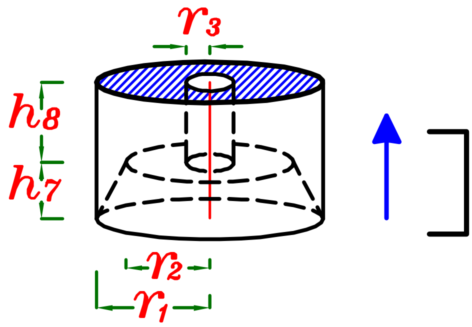
Sec. ③ أعلى ال support



عند **Sec. ③** سيكون ضغط الماء بعيدا عن ال **support** كله لاعلى .

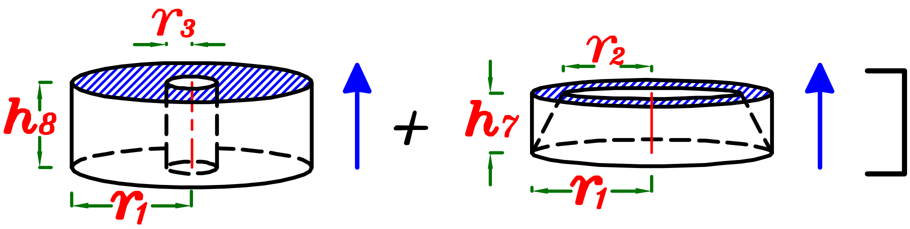


$$W_\phi = \gamma_w * \Big[\textbf{Volume of}$$



$$\uparrow \Big]$$

$$W_\phi = \gamma_w * \Big[\textbf{Volume of}$$

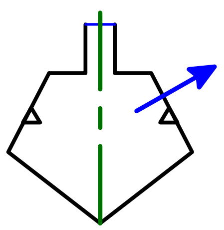


$$\uparrow \Big]$$

$\boxed{\gamma_w = 10\ kN/m^3}$

اشاره W_ϕ $(-Ve)$ لان اتجاهها خارج من ال **Support**

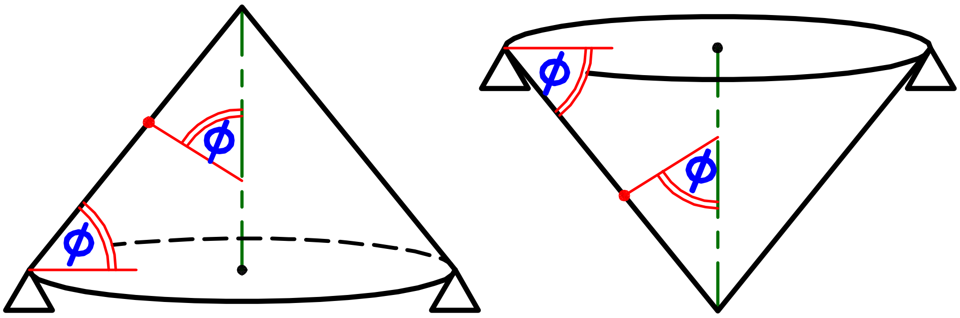
اشاره Z $(-Ve)$
لان اتجاهها خارج من المحور



عند **Sec. ③** $\boxed{Z = \gamma_w * h_5}$

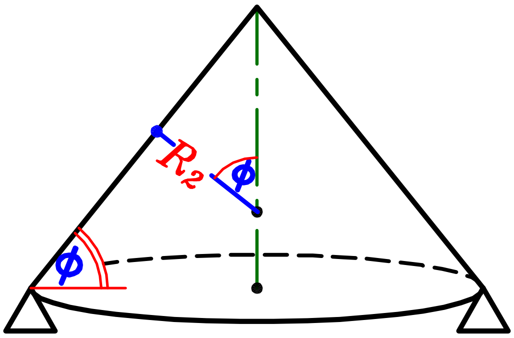
Cone.

ϕ هى زاويه ميل السطح مباشره مع الافقى .



$$\boxed{R_1 = \infty} \qquad \because \frac{T_1}{R_1} + \frac{T_2}{R_2} = Z$$

$$\therefore \ Zero + \frac{T_2}{R_2} = Z$$

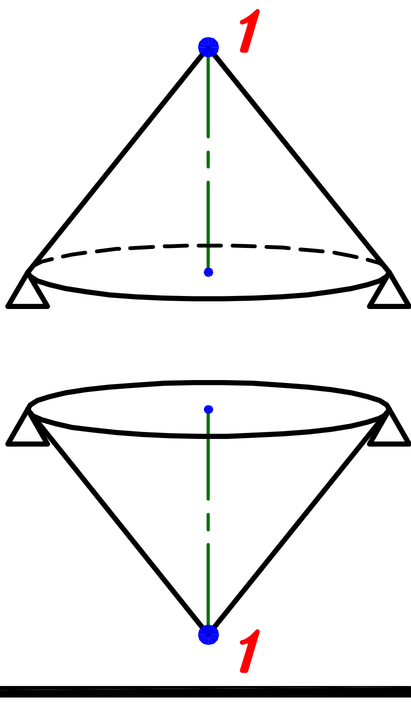


$$\boxed{T_2 = R_2 \, Z}$$ حفظ

At Cone Vertex Point ①

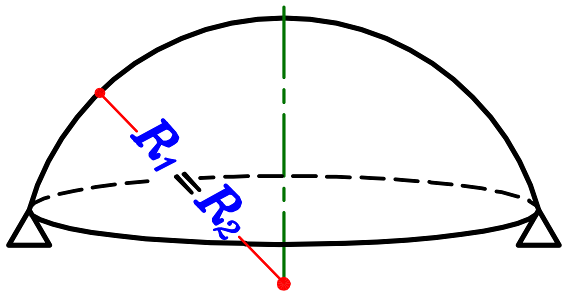
$$\boxed{T_1 = T_2 = Zero}$$ حفظ

129 اثباته فى صفحه



Dome.

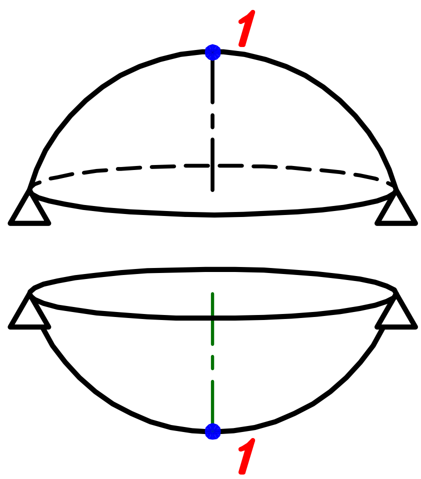
$$\boxed{R_1 = R_2 = R}$$



$$\because \quad \frac{T_1}{R_1} + \frac{T_2}{R_2} = Z \qquad \therefore \quad \frac{T_1 + T_2}{R} = Z$$

$$\boxed{T_1 + T_2 = R\,Z}$$ حفظ

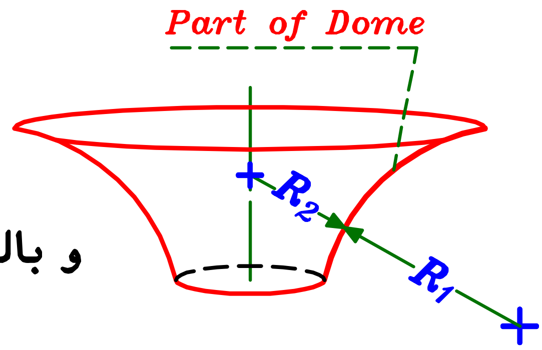
At Dome Vertex Point ①



$$\boxed{T_1 = T_2 = \frac{R\,Z}{2}}$$ حفظ

اثباته فى صفحه 130

Special Case.

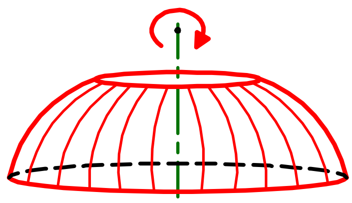


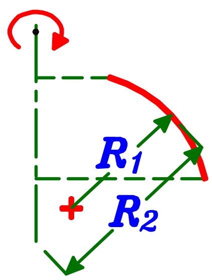
اذا كان المنحنى للخارج ستكون $\boxed{R_1 \neq R_2}$

و بالتالى معادله $\boxed{T_1 + T_2 = R\,Z}$ لن تكون صحيحه

و سنضطر لاستخدام المعادله الاصليه $\boxed{\frac{T_1}{R_1} + \frac{T_2}{R_2} = Z}$

Special Case.





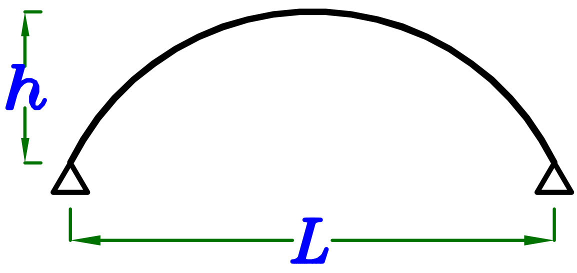
اذا كان المنحنى للداخل لكن مركزه ليس على ال **A.O.R.**

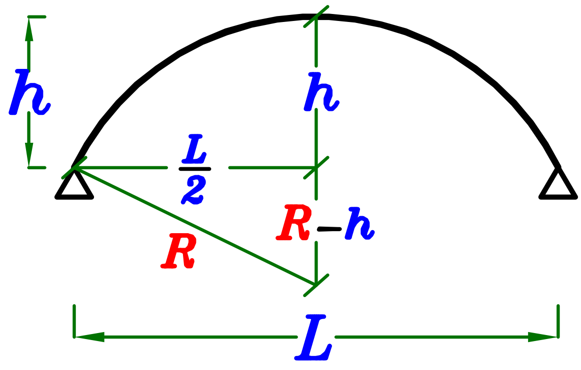
ستكون $\boxed{R_1 \neq R_2}$ و بالتالى معادله $\boxed{T_1 + T_2 = R\,Z}$ لن تكون صحيحه .

و سنضطر لاستخدام المعادله الاصليه $\boxed{\frac{T_1}{R_1} + \frac{T_2}{R_2} = Z}$

Calculations of Dome Radius.

من الممكن ان يكون معطى لل *Dome* عرض قاعدتها و ارتفاعها .
و بالطبع سنحتاج ان نحدد نصف قطرها لتكمله حسابات المسأله .





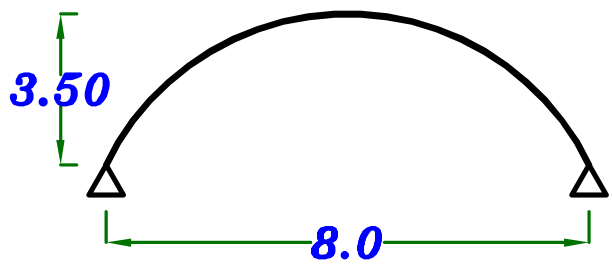
$$R^2 = \left(\frac{L}{2}\right)^2 + (R-h)^2$$

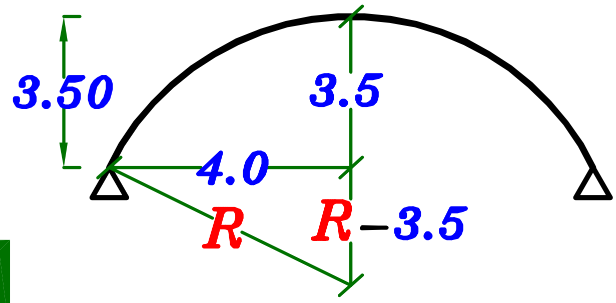
$$\cancel{R^2} = \frac{L^2}{4} + \cancel{R^2} - 2Rh + h^2$$

$$R = \frac{L^2/4 + h^2}{2h}$$

Example.

Find the radius
For the given Dome.





$$R^2 = 4.0^2 + (R-3.5)^2$$

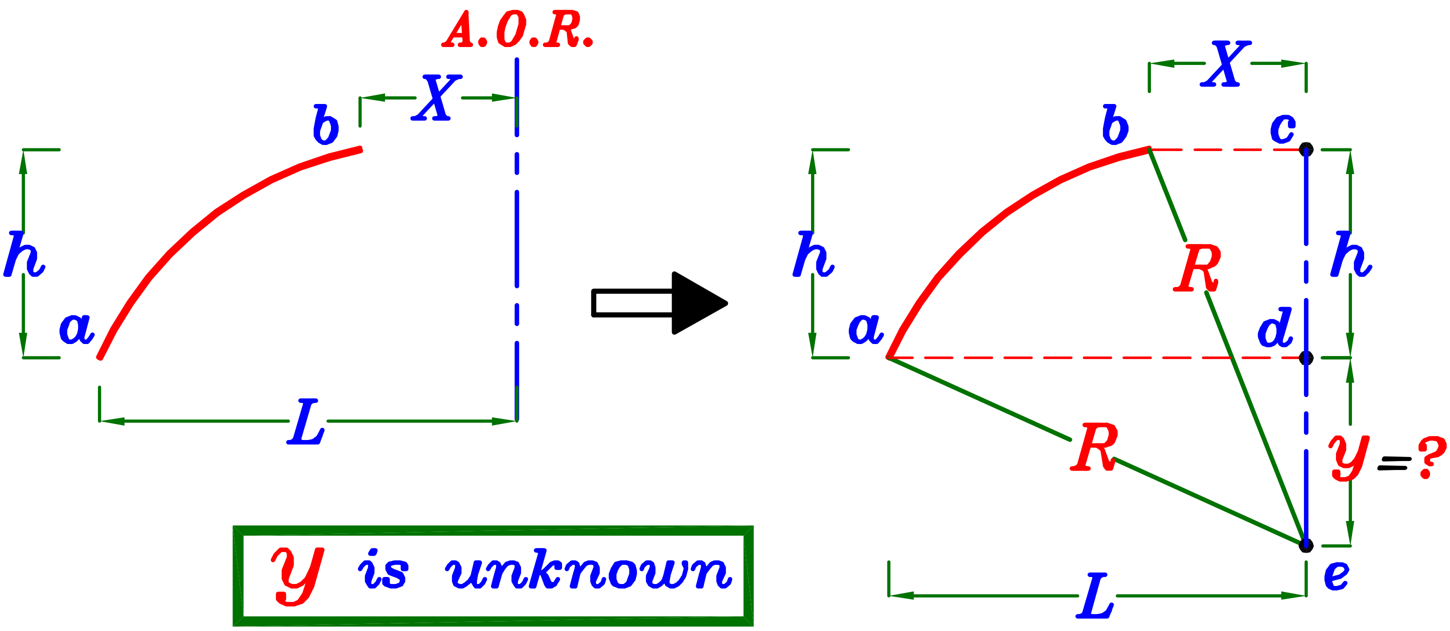
$$\cancel{R^2} = 16 + \cancel{R^2} - 7.0R + 12.25$$

$$7.0R = 28.25 \longrightarrow \boxed{R = 4.03\,m}$$

اذا كان معطى جزء من ال *Dome* و لا توجد *Vertex*

و معطى فقط ارتفاع هذا الجزء و عرضه و بعده الافقى عن المحور .

و بالطبع سنحتاج ان نحدد نصف قطرها لتكمله حسابات المسأله .



y is unknown

For Triangle a d e

$$R^2 = L^2 + y^2 \quad \underline{\quad R\,,\,y \quad} \; (1)$$

For Triangle e c b

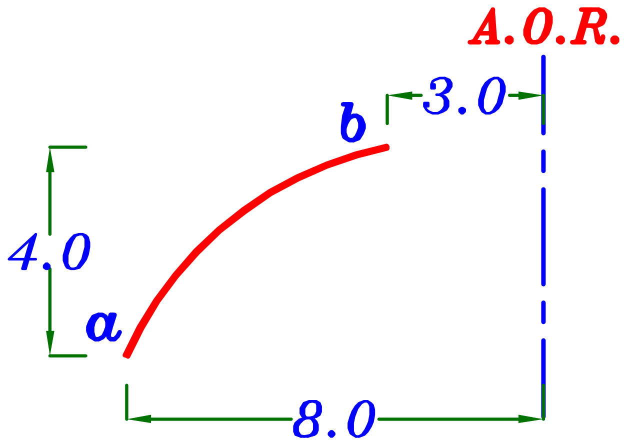
$$R^2 = X^2 + (y+h)^2 = X^2 + y^2 + 2\,y\,h + h^2$$

$$R^2 = X^2 + y^2 + 2\,y\,h + h^2 \quad \underline{\quad R\,,\,y \quad} \; (2)$$

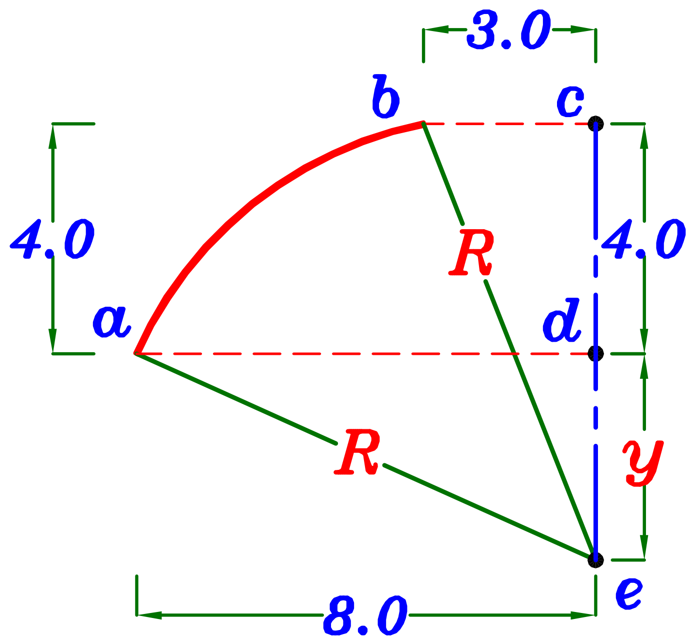
Solve the Two equations and Get y, R

Example.

Find the radius For the Dome Contains the Arch ab



For Triangle ade



$$R^2 = 8.0^2 + y^2$$

$$\therefore R^2 = 64 + y^2 \quad \text{-------} \; R, y \; (1)$$

For Triangle ecb

$$R^2 = 3.0^2 + (y + 4.0)^2$$

$$R^2 = 9.0 + y^2 + 8.0\,y + 16.0$$

$$R^2 = 25.0 + y^2 + 8.0\,y \quad \text{-------} \; R, y \; (2)$$

بتعويض R^2 من المعادله الاولى فى المعادله الثانيه

$$\therefore 64 + \cancel{y}^2 = 25.0 + \cancel{y}^2 + 8.0\,y \longrightarrow y = 4.875\ m$$

$$\therefore R^2 = 64 + 4.875^2 = 87.76\ m^2 \longrightarrow \boxed{R = 9.37\ m}$$

Special Case.

ممكن تأجيل قراءه هذه الحالة حتى الانتهاء من الدرس و بدء حل الامثله

اذا كان المنحنى للخارج (كما بالشكل فى الاسفل) ستكون $\boxed{R_1 \neq R_2}$

و يجب ان يكون نصف قطر المنحنى (R_1) معطى لكى نستطيع تكمله حسابات المسأله.

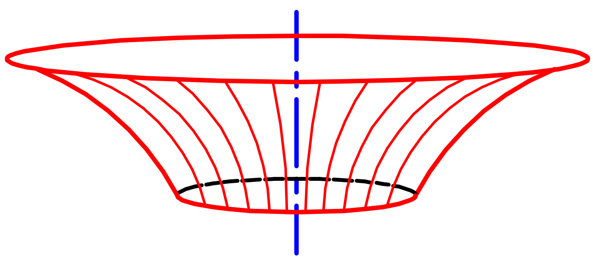
سنحتاج لتحديد مكان المحور (Y) الذى يوجد عنده مركز الدائره المكونه لهذا المنحنى .

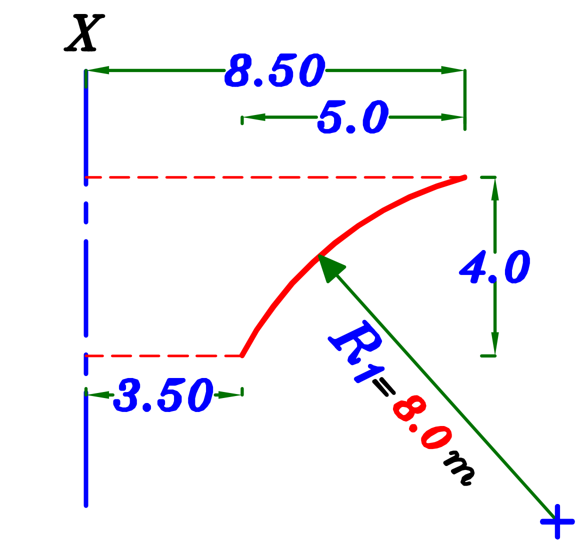
ثم نحدد المسافه الافقيه بين المحور (Y) و محور الدوران (X) .

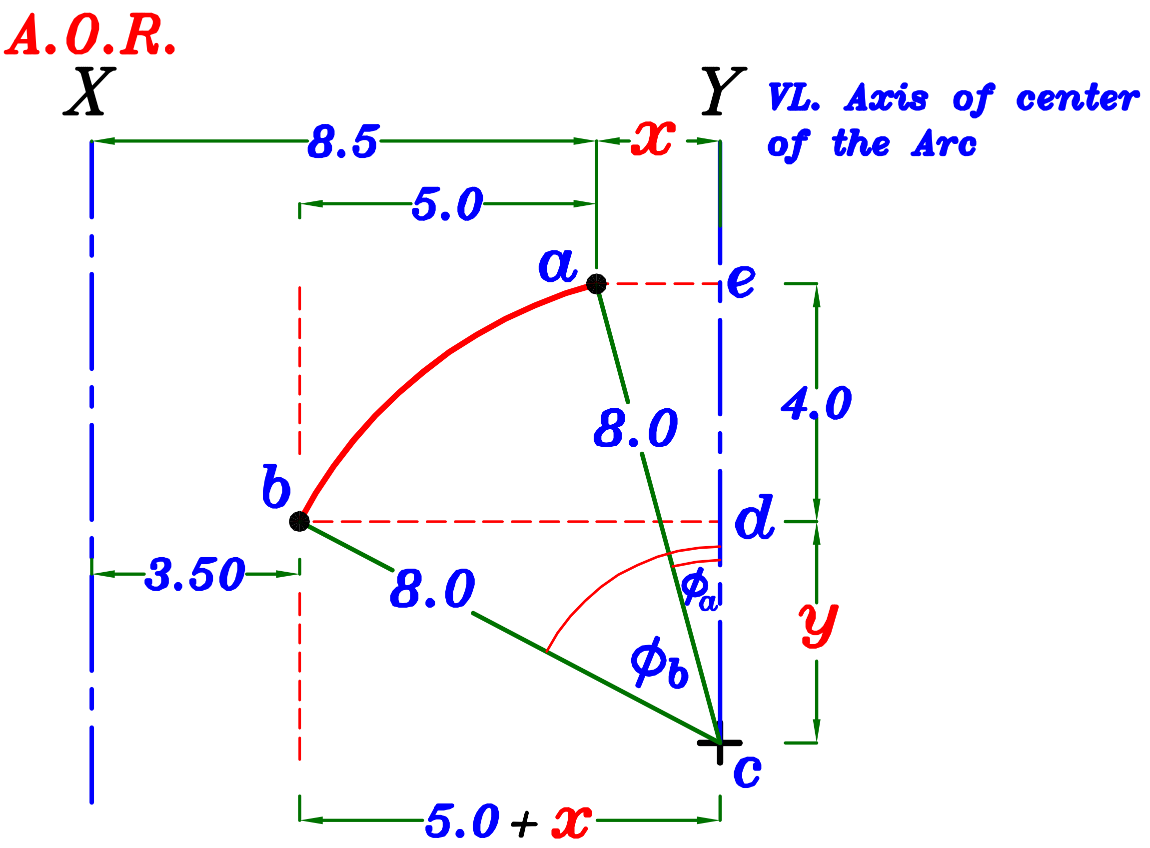
Example.

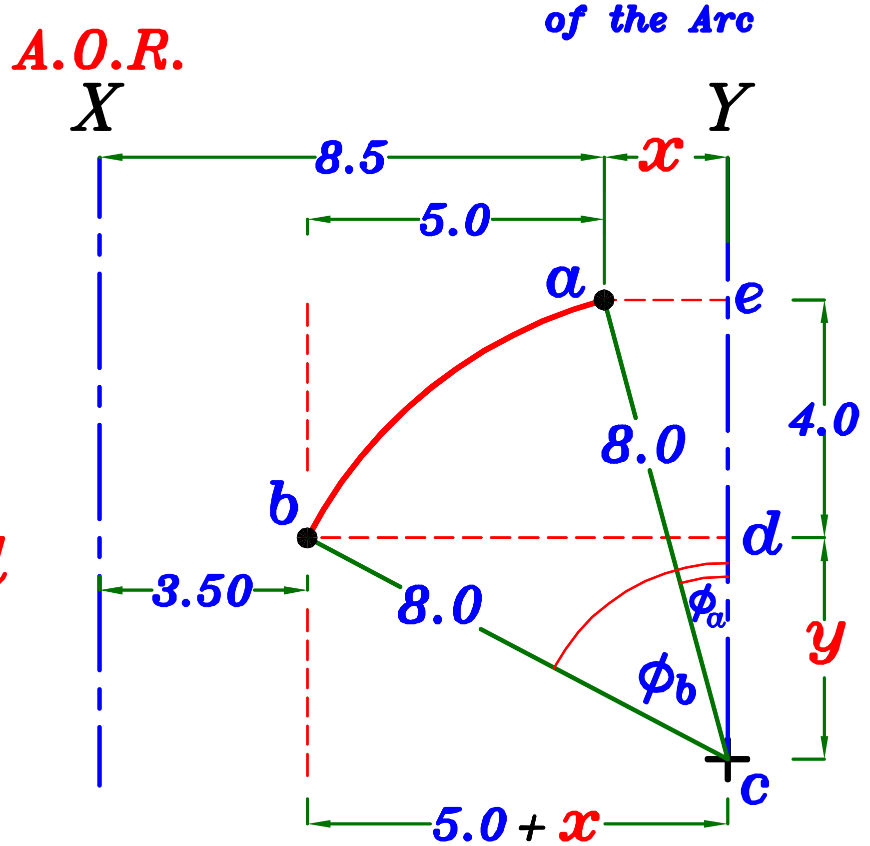
Find The surface Area

For the Given Dome.









For Triangle b c d

$$8.0^2 = y^2 + (x+5.0)^2$$

$$64 = y^2 + (x+5.0)^2$$

$$\therefore y^2 = 64 - (x+5.0)^2 \quad \text{---}x,y\text{---} (1)$$

For Triangle a c e

$$8.0^2 = x^2 + (y+4)^2$$

$$\therefore 64 = x^2 + (y+4)^2 \quad \text{---}x,y\text{---} (2)$$

Substitution From (1) in (2)

$$\therefore 64 = x^2 + (y+4)^2 = x^2 + y^2 + 8y + 16$$

$$\therefore \cancel{64} = x^2 + \cancel{64} - (x+5)^2 + 8 * \sqrt{64-(x+5)^2} + 16$$

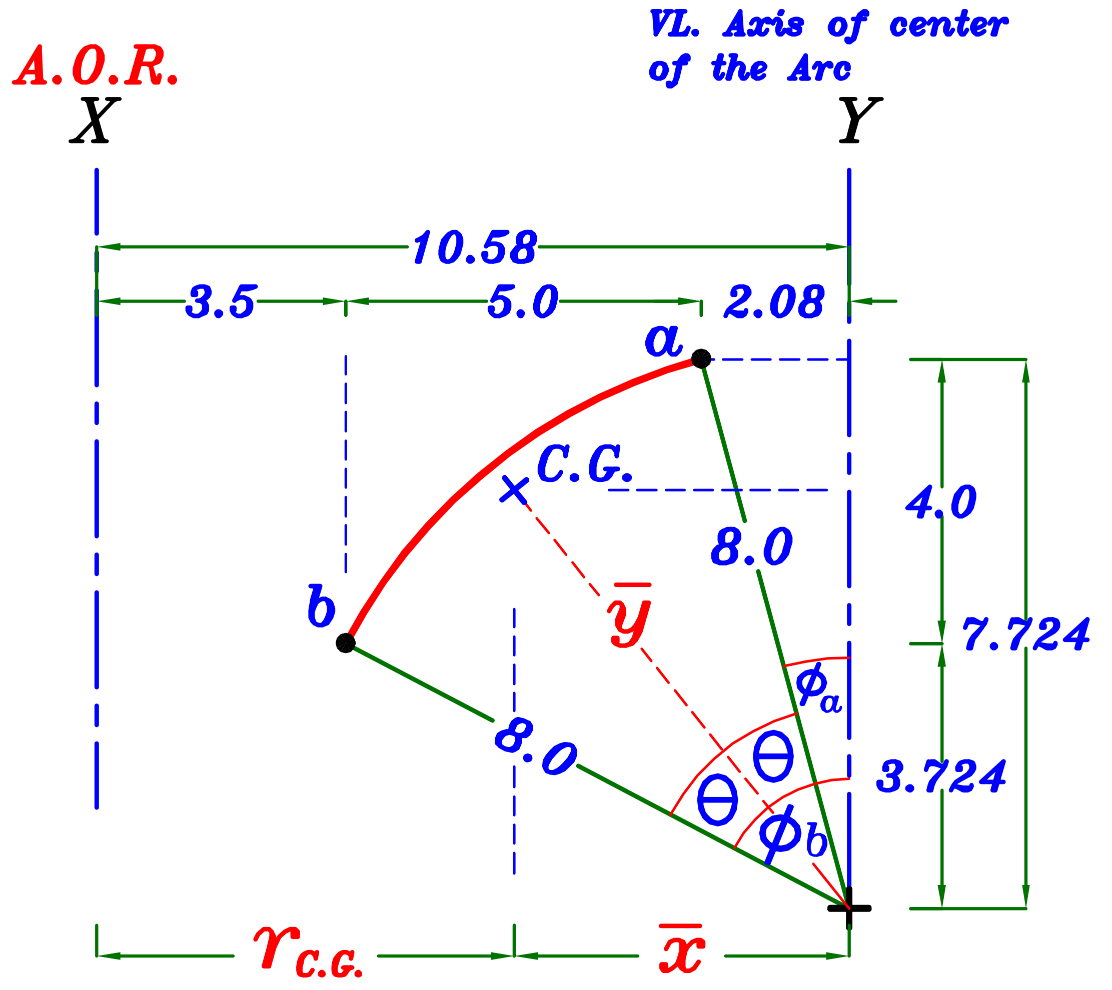
$$0.0 = x^2 - (x^2 + 10x + 25) + 8 * \sqrt{64-(x+5)^2} + 16$$

$$0.0 = \cancel{x^2} - \cancel{x^2} - 10x - 25 + 8 * \sqrt{64-(x+5)^2} + 16$$

$$0.0 = -10x - 9.0 + 8 * \sqrt{64-(x+5)^2} \longrightarrow \boxed{x = 2.08\ m}$$

$$\because y^2 = 64 - (x+5)^2 = 64 - (2.08+5)^2$$

$$\therefore y^2 = 13.873 \longrightarrow \boxed{y = 3.724\ m}$$



$$\sin\phi_a = \frac{2.08}{8.0} \longrightarrow \boxed{\phi_a = 15.07^\circ}$$

$$\cos\phi_b = \frac{3.724}{8.0} \longrightarrow \boxed{\phi_b = 62.257^\circ}$$

Central Angle $\theta = \dfrac{\phi_b - \phi_a}{2} = \dfrac{62.257 - 15.07}{2} = 23.59^\circ$

$$\bar{y} = \frac{R * \sin\theta}{\theta} = \frac{8.0 * \sin 23.59^\circ}{23.59 * \pi \backslash 180} = 7.775 \text{ m}$$

$\because \sin(\phi_a + \theta) = \dfrac{\bar{x}}{\bar{y}}$ $\therefore \sin(15.07 + 23.59) = \dfrac{\bar{x}}{7.775} \longrightarrow \bar{x} = 4.857 \text{ m}$

$r_{C.G.}$ = Distance between the Two axes $- \bar{x}$

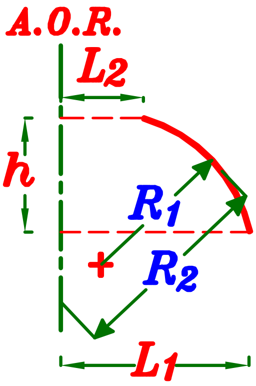
$$r_{C.G.} = 10.58 - 4.857 = 5.723 \text{ m}$$

Arc Length $= 2 * R * \theta = 2 * 8.0 * 23.59 * \dfrac{\pi}{180} = 6.587 \text{ m}$

S.A. = Arc Length $* 2\pi * r_{C.G.} = 6.587 * 2\pi * 5.723 = 236.86 \text{ m}^2$

Special Case.

ممكن تأجيل قراءه هذه الحاله حتى الانتهاء من الدرس و بدء حل الامثله



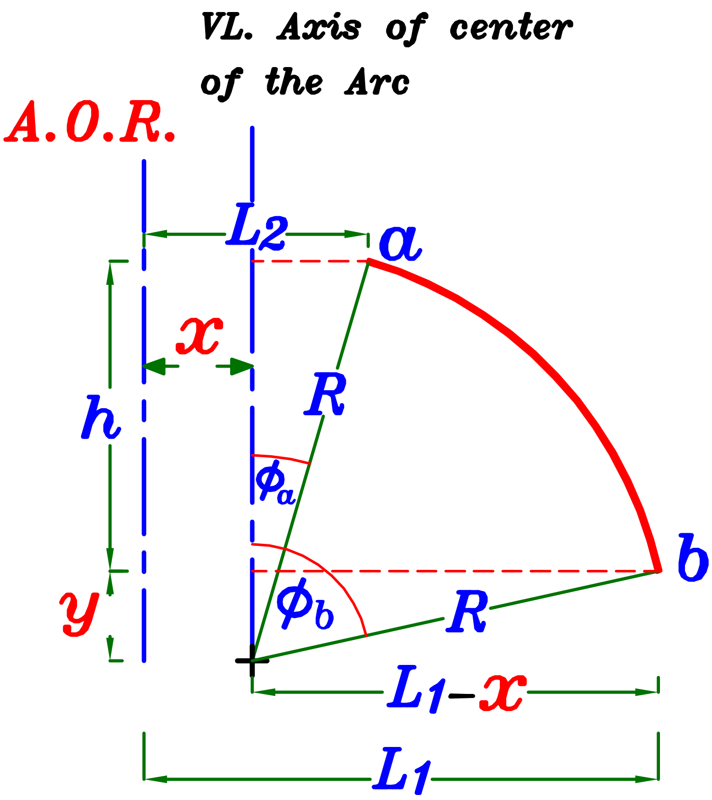
اذا كان المنحنى للداخل لكن مركزه ليس على ال A.O.R.

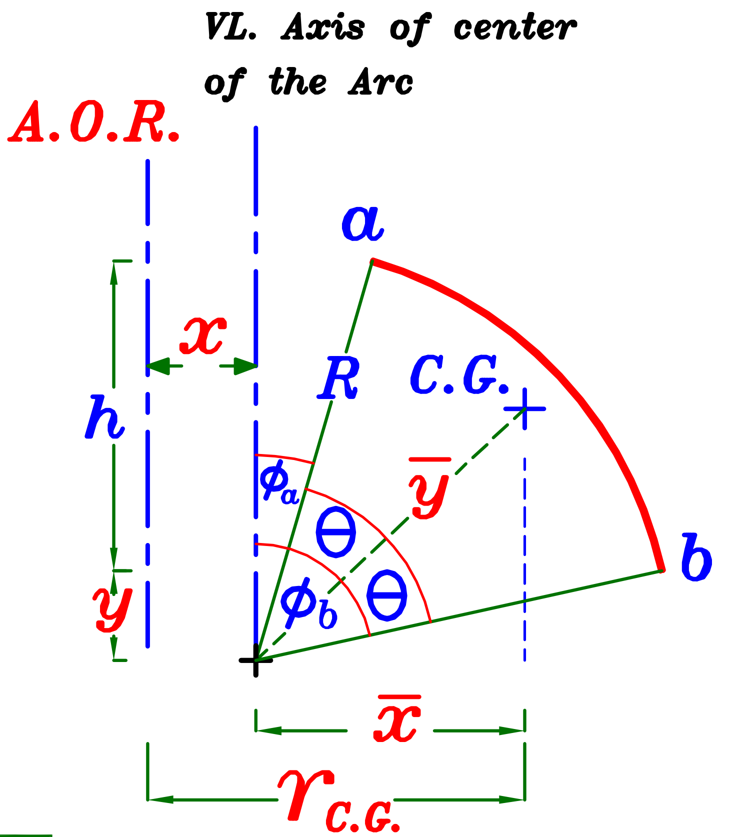
ستكون $\boxed{R_1 \neq R_2}$

و يجب ان يكون نصف قطر المنحنى (R_1) معطى لكى نستطيع تكمله حسابات المسأله.

سنحتاج لتحديد مكان المحور (Y) الذى يوجد عنده مركز الدائره المكونه لهذا المنحنى .

ثم نحدد المسافه الافقيه بين المحور (Y) و محور الدوران (X) .





$$\boxed{S.A. = \text{Arc Length} * 2\pi * r_{C.G.}}$$

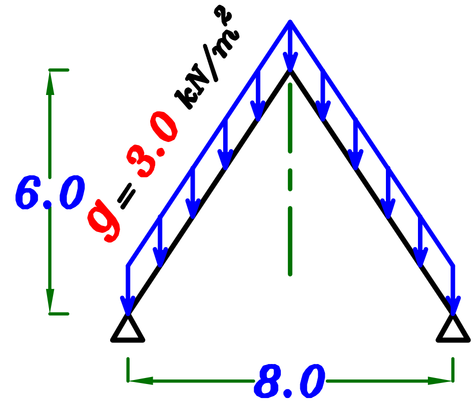
$$\boxed{\text{Arc Length} = 2 * R * \theta}$$

$$\boxed{\bar{y} = \frac{R * \sin\theta}{\theta}}$$

Example.

Draw T_1 & T_2 distribution on the vertical projection of the Cone due to dead load only.

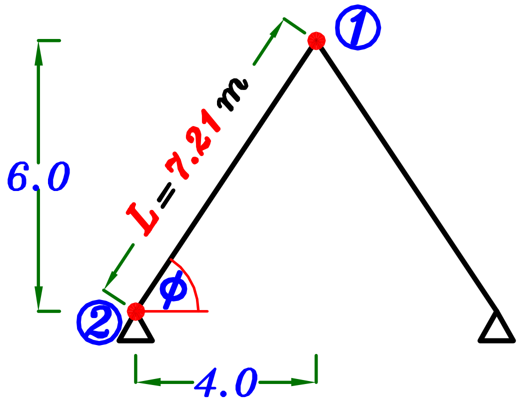
$g = 3.0\ kN/m^2$



$\tan\phi = \dfrac{6.0}{4.0} \longrightarrow \boxed{\phi = 56.31^\circ}$

$L^2 = 6.0^2 + 4.0^2 \longrightarrow \boxed{L = 7.21\ m}$

$R_1 = \infty$



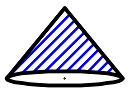
Sec. ①

$T_1 = T_2 = Zero$

Sec. ②

$r = 4.0\ m$

$S.A. = \pi * r * L = \pi * 4.0 * 7.21 = 90.60\ m^2$



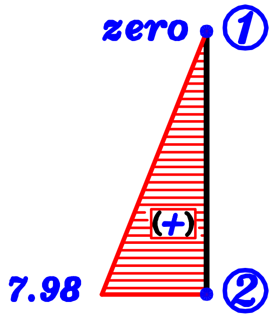
$W\phi = g * S.A. = 3.0 * 90.60 = +\ 271.8\ kN$

$T_1 = \dfrac{W\phi}{2\pi r\ \sin\phi} = \dfrac{+\ 271.8}{2\pi * 4.0 * \sin 56.31^\circ} = +\ 13.0\ kN/m$ Comp.

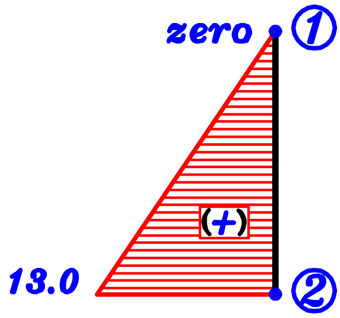
$Z = g \cos\phi = 3.0 * \cos 56.31^\circ = +\ 1.664\ kN/m^2$

$R_2 = \dfrac{r}{\sin\phi} = \dfrac{4.0}{\sin 56.31^\circ} = 4.80\ m$

$\because\ T_2 = Z * R_2 = 1.664 * 4.80 = +\ 7.98\ kN/m$ Comp.



T_2 Diagram (kN/m)

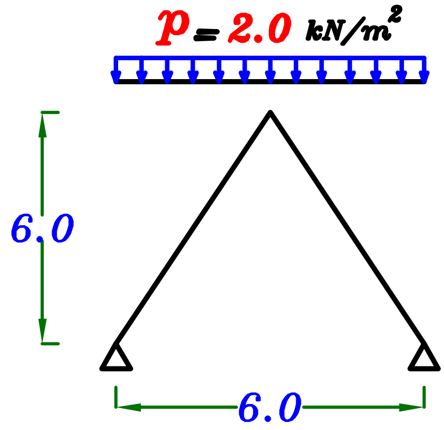


T_1 Diagram (kN/m)

Example.

Draw T_1 & T_2 distribution on the vertical projection of the Cone due to live load only.

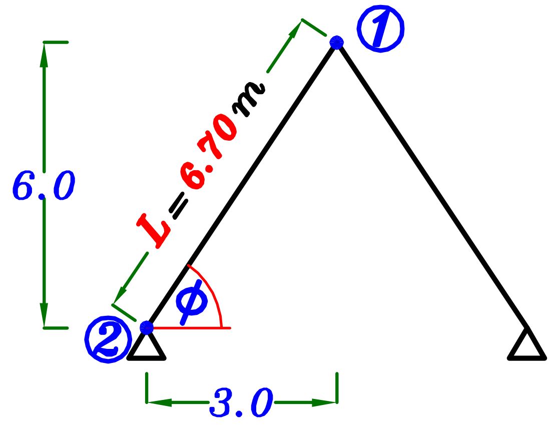
$p = 2.0\ kN/m^2$



$\tan\phi = \dfrac{6.0}{3.0} \longrightarrow \boxed{\phi = 63.43^\circ}$

$L^2 = 6.0^2 + 3.0^2 \longrightarrow \boxed{L = 6.70\ m}$

$R_1 = \infty$



Sec. ① $\quad T_1 = T_2 = Zero$

Sec. ② $\quad r = 3.0\ m$

Projected area $= \pi * r^2 = \pi * 3.0^2 = 28.27\ m^2$

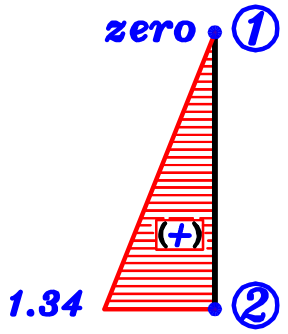
$W_\phi = p *$ Projected area $= 2.0 * 28.27 = +56.54\ kN$

$T_1 = \dfrac{W_\phi}{2\pi r\ \sin\phi} = \dfrac{+56.54}{2\pi * 3.0 * \sin 63.43^\circ} = +3.35\ kN/m$ Comp.

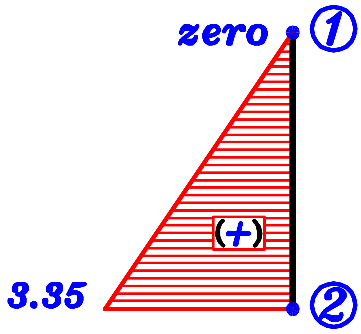
$Z = p\cos^2\phi = 2.0 * \cos^2 63.43^\circ = +0.40\ kN/m^2$

$R_2 = \dfrac{r}{\sin\phi} = \dfrac{3.0}{\sin 63.43^\circ} = 3.35\ m$

$\because\ T_2 = Z * R_2 = 0.40 * 3.35 = +1.34\ kN/m$ Comp.



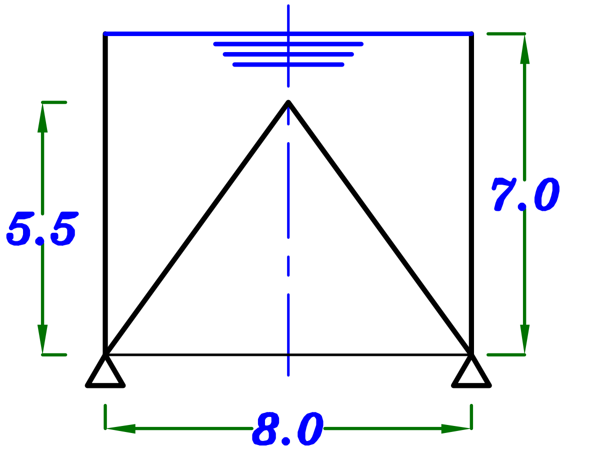
T_2 Diagram (kN/m)



T_1 Diagram (kN/m)

Example.

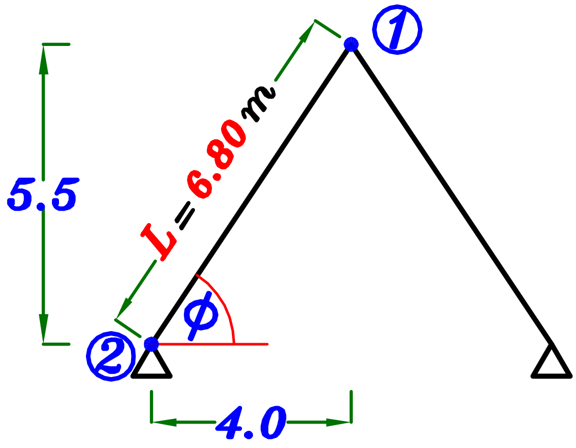
Draw T_1 & T_2 distribution on the vertical projection of The Cone due to water pressure.



$$\tan\phi = \frac{5.5}{4.0} \longrightarrow \boxed{\phi = 53.97^\circ}$$

$$L^2 = 6.0^2 + 4.0^2 \longrightarrow \boxed{L = 6.80\,m}$$

$$R_1 = \infty$$

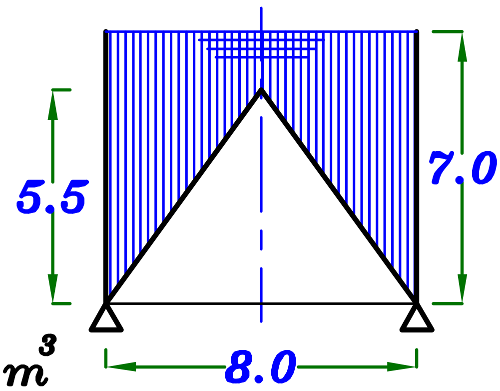


Sec. 1

$$T_1 = T_2 = Zero$$

Sec. 2

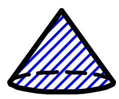
$$r = 4.0\ m$$



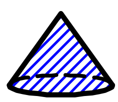
Volume of Cylinder $= \pi * r^2 * h$

$= \pi * 4.0^2 * 7.0 = 351.85\ m^3$

Volume of Cone $= \frac{1}{3} * \pi * r^2 * h$



$= \frac{1}{3} * \pi * 4.0^2 * 5.5 = 92.15\ m^3$

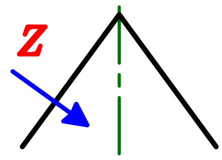
Volume of Water  $=$   $351.85 - 92.15 = 259.7\ m^3$

$$W_\phi = \gamma_w * Volume = 10.0 * 259.7 = +2597.0\ kN \downarrow$$

$$T_1 = \frac{W_\phi}{2\pi r \; Sin\phi} = \frac{+2597.0}{2\pi * 4.0 * Sin\, 53.97^\circ} = +\, 127.77 \; kN/m \quad Comp.$$

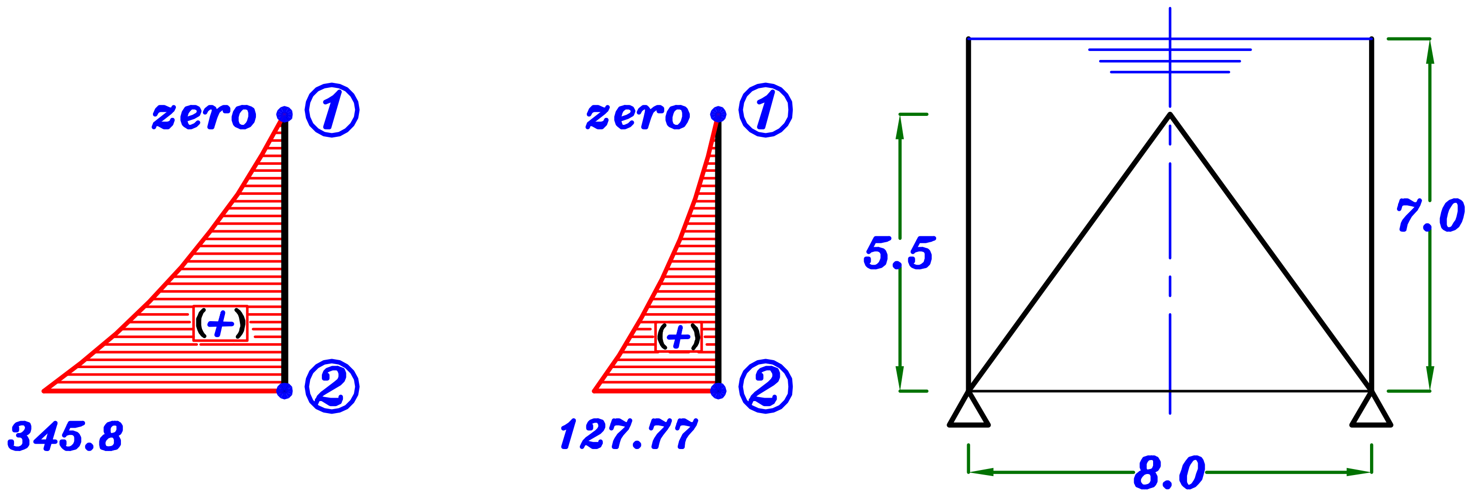
$$Z = \gamma_w * h = 10.0 * 7.0 = +\, 70 \; kN/m^2$$

اشاره Z $(+Ve)$ لان اتجاهها داخل الى المحور



$$R_2 = \frac{r}{Sin\phi} = \frac{4.0}{Sin\, 53.97^\circ} = 4.94 \; m$$

$$\because \; T_2 = Z * R_2 = 70.0 * 4.94 = +\, 345.8 \; kN/m \quad Comp.$$

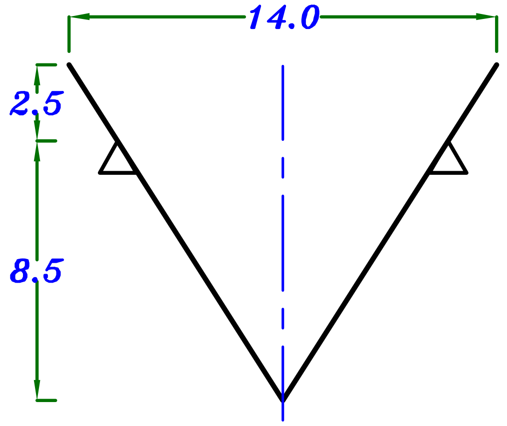


T_2 Diagram (kN/m) T_1 Diagram (kN/m)

Example.

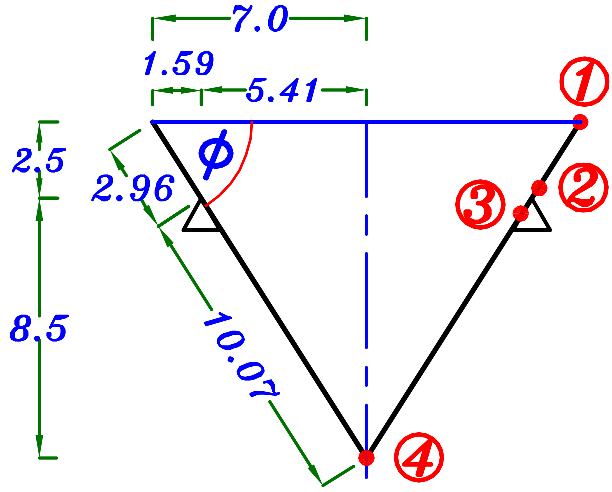
Draw T_1 & T_2 distribution on the vertical projection. due to dead load only.

$g = 3.0 \ kN/m^2$



$\tan\phi = \dfrac{11}{7.0} \longrightarrow \boxed{\phi = 57.53^\circ}$

$R_1 = \infty$



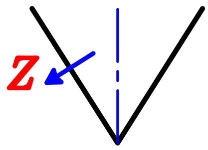
Sec. 1

$r = 7.0 \ m$

$W_\phi = Zero \longrightarrow T_1 = Zero$

$Z = g \cos\phi = 3.0 * \cos 57.53^\circ = -1.61 \ kN/m^2$

$\boxed{\text{اشاره } Z \ (-Ve) \text{ لان اتجاهها خارج من المحور}}$

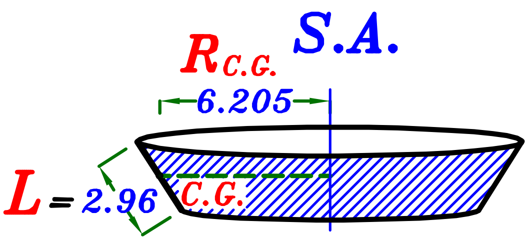


$R_2 = \dfrac{r}{\sin\phi} = \dfrac{7.0}{\sin 57.53^\circ} = 8.297 \ m$

$T_2 = Z * R_2 = -1.61 * 8.297 = -13.35 \ kN/m$ Ten.

Sec. 2

$r = 5.41 m$



$S.A. = L * 2\pi * R_{C.G.}$

$= 2.96 * 2\pi * 6.205 = 115.4 \ m^2$

$W_\phi = g * S.A. = 3.0 * 115.4 = +346.2 \ kN$

$T_1 = \dfrac{W_\phi}{2\pi r \sin\phi} = \dfrac{+346.2}{2\pi * 5.41 * \sin 57.53^\circ} = +12.07 \ kN/m$ Comp.

$$Z = g \cos\phi = -1.61 \ kN/m^2$$

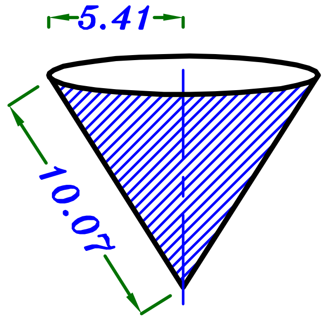
$$R_2 = \frac{r}{\sin\phi} = \frac{5.41}{\sin 57.53^\circ} = 6.41 \ m$$

$$T_2 = Z * R_2 = -1.61 * 6.41 = -10.32 \ kN/m \ \text{Ten.}$$

Sec. ③

$r = 5.41 \, m$

S.A.



$$S.A. = \pi * L * r = \pi * 10.07 * 5.41 = 171.15 \ m^2$$

$$W_\phi = g * S.A. = 3.0 * 171.15 = -513.45 \ kN$$

اشاره W_ϕ (−Ve) لان اتجاهها خارج من ال Support

$$T_1 = \frac{W_\phi}{2\pi r \sin\phi} = \frac{-513.45}{2\pi * 5.41 * \sin 57.53^\circ} = -17.90 \ kN/m \ \text{Ten.}$$

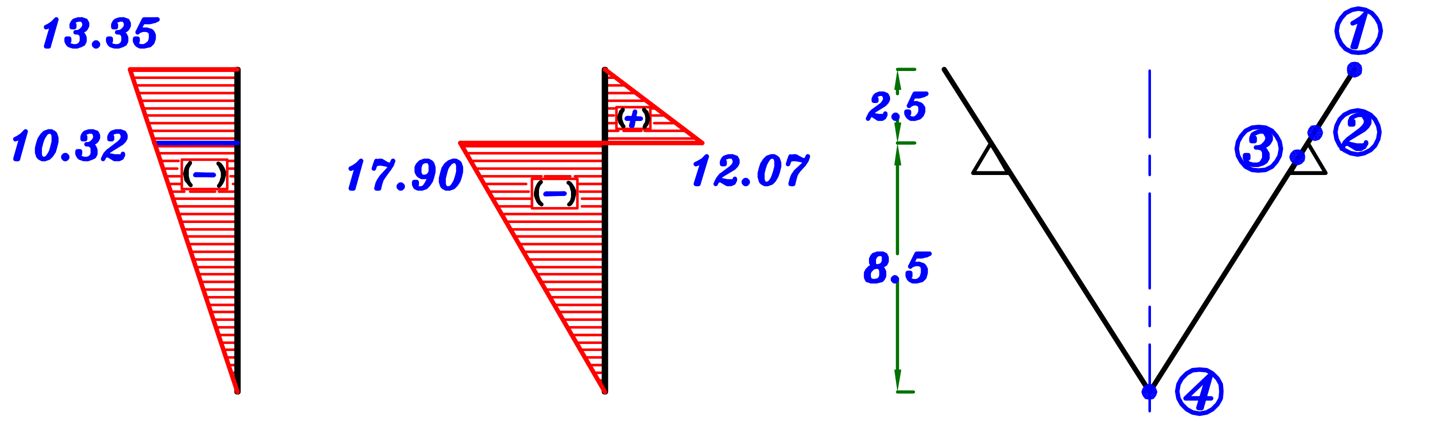
$$R_2 = \frac{r}{\sin\phi} = \frac{5.41}{\sin 57.53^\circ} = 6.41 \ m$$

$$T_2 = Z * R_2 = -1.61 * 6.41 = -10.32 \ kN/m \ \text{Ten.}$$

Sec. ④

Vertex of the Cone.

$$T_1 = T_2 = \text{Zero}$$

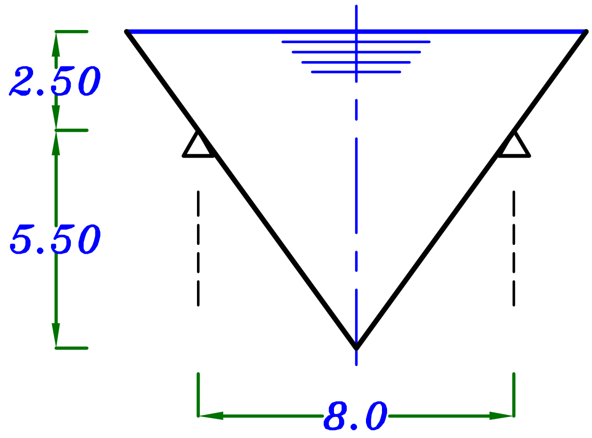


T_2 Diagram (kN/m)

T_1 Diagram (kN/m)

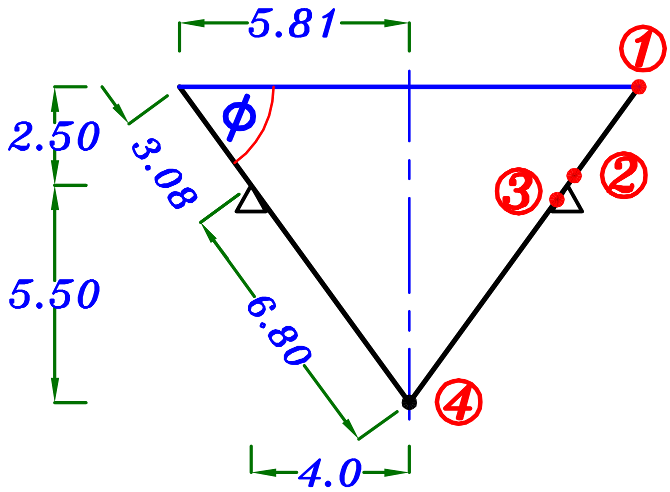
Example.

Draw T_1 & T_2 distribution on the vertical projection due to water pressure.



$\tan\phi = \frac{5.5}{4.0} \longrightarrow \boxed{\phi = 53.97^\circ}$

$R_1 = \infty$



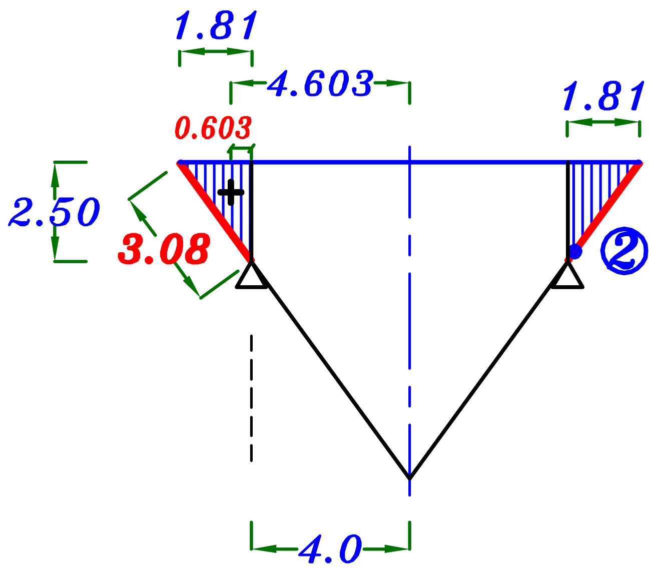
Sec. 1

$r = 5.1\ m$

$W_\phi = Zero \longrightarrow T_1 = Zero$

$Z = \gamma_w * h = \gamma_w * Zero = Zero$

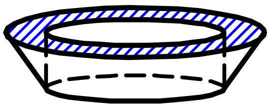
$T_2 = Z * R_2 = Zero$

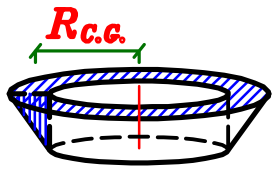


Sec. 2

$r = 4.0\ m$

Volume of water =





$= Area * 2\pi * R_{c.G.}$

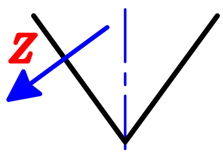
$$\text{Volume of water} = \left(\frac{1}{2} * 1.81 * 2.5\right) * 2\pi * 4.603 = 65.43\ m^3$$

$$W_\phi = \gamma_w * Volume = 10.0 * 65.43 = +654.3\ kN$$

$$T_1 = \frac{W_\phi}{2\pi r\ \sin\phi} = \frac{+654.3}{2\pi * 4.0 * \sin 53.97^\circ} = +32.19\ \ kN/m\ \ \text{Comp.}$$

$$Z = \gamma_w * h = 10.0 * 2.5 = -25\ kN/m^2$$

اشاره Z $(-Ve)$ لان اتجاهها خارج من المحور

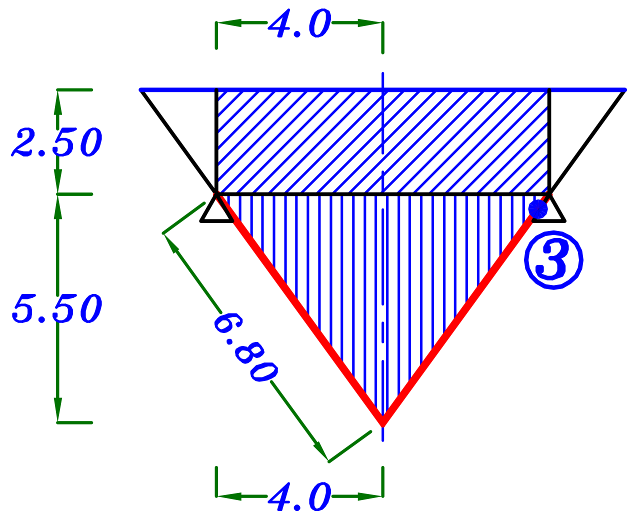


$$R_2 = \frac{r}{Sin\phi} = \frac{4.0}{Sin\,53.97^\circ} = 4.94\ m$$

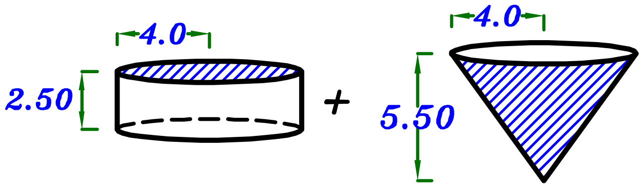
$$\because\ T_2 = Z * R_2 = -25 * 4.94 = -123.5\ kN/m\ \ Ten.$$

Sec. ③

$r = 4.0\ m$



Volume of water =



$$\text{Volume of water} = \pi r^2 * h + \frac{1}{3} * \pi * r^2 * h$$

$$= \pi * 4.0^2 * 2.5 + \frac{1}{3} * \pi * 4.0^2 * 5.5 = 217.82\ m^3$$

$$W_\phi = \gamma_w * Volume = 10.0 * 217.8 = -2178.2\ kN$$

اشاره W_ϕ $(-Ve)$ لان اتجاهها خارج من ال Support

$$T_1 = \frac{W_\phi}{2\pi r\ Sin\phi} = \frac{-2178.2}{2\pi * 4.0 * Sin\,53.97^\circ} = -107.17\ kN/m\ \ Comp.$$

$$Z = \gamma_w * h = 10.0 * 2.5 = -25\ kN/m^2$$

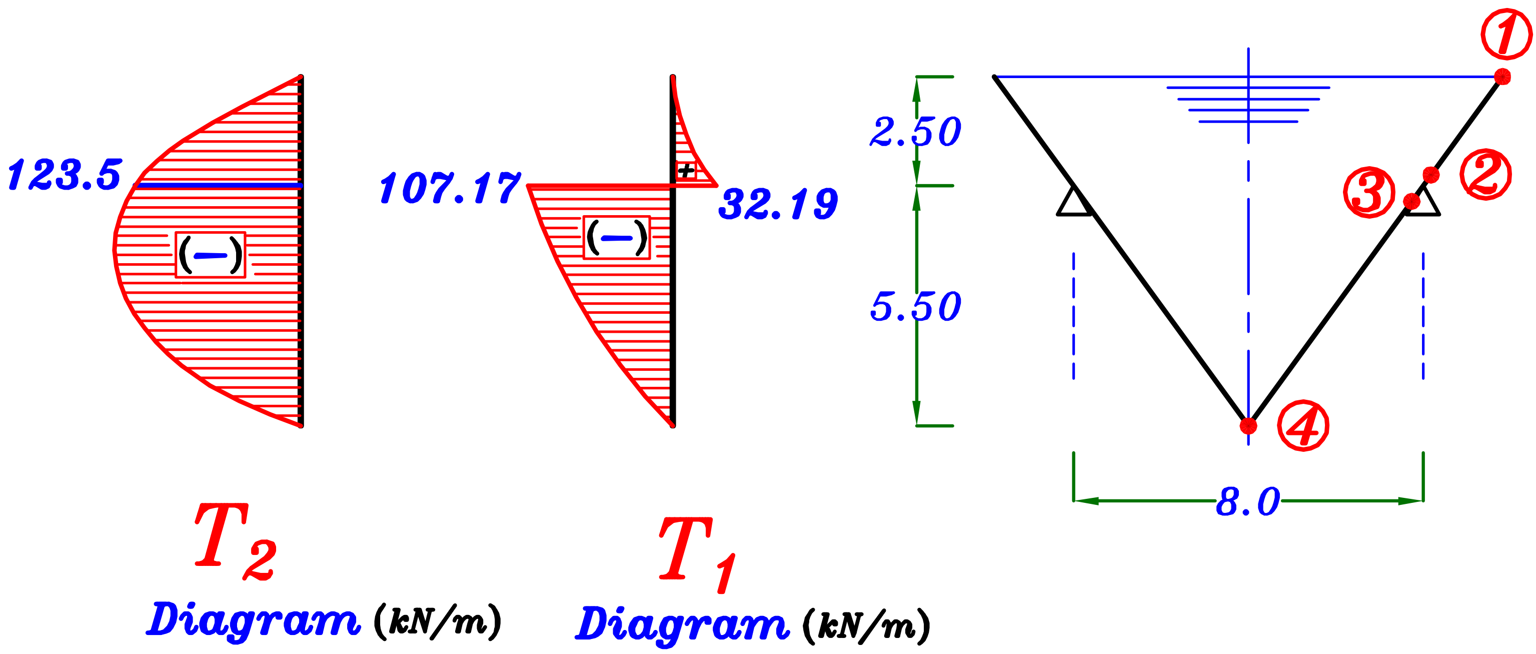
اشاره Z $(-Ve)$ لان اتجاهها خارج من المحور

$$R_2 = \frac{r}{Sin\phi} = \frac{4.0}{Sin\,53.97^\circ} = 4.94\ m$$

$$\because\ T_2 = Z * R_2 = -25 * 4.94 = -123.5\ kN/m\ \ Ten.$$

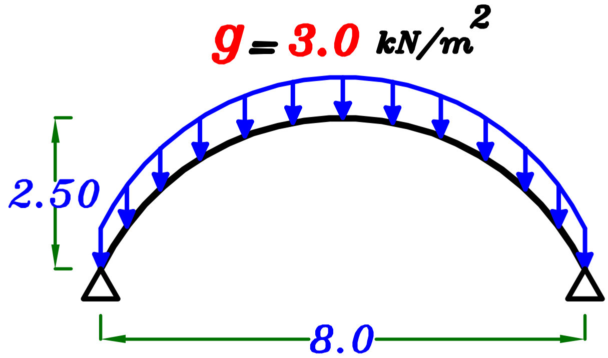
Sec. ④ Vertex of the Cone.

$$T_1 = T_2 = Zero$$



Example.

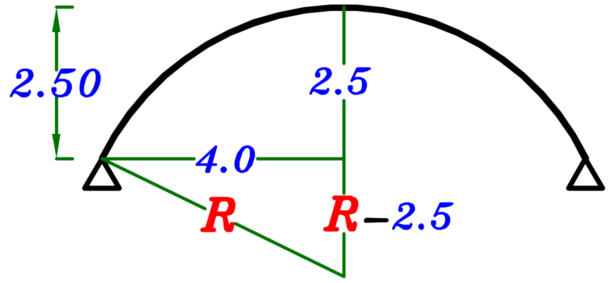
Draw T_1 & T_2 distribution (at least 3 points) on the vertical projection of the Dome due to Dead load only. $g = 3.0\ kN/m^2$



$$R^2 = 4.0^2 + (R - 2.5)^2$$

$$R^2 = 16 + R^2 - 5R + 6.25$$

$$5R = 22.25 \longrightarrow \boxed{R = 4.45\ m}$$

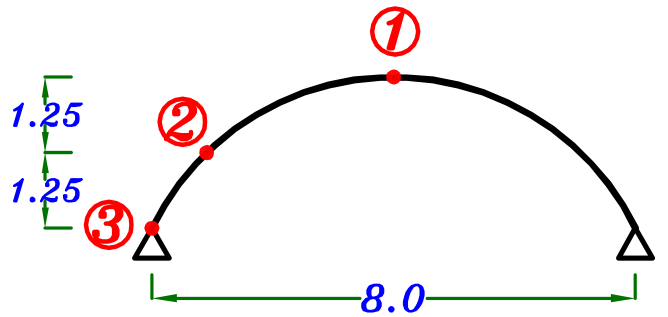


Sec. ①

$\phi = Zero$

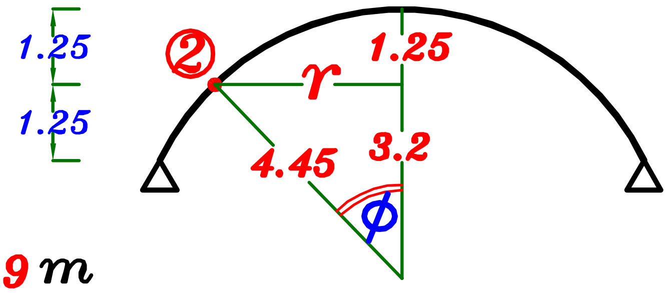
$$Z = g\ Cos\,\phi = 3.0 * Cos\ 0.0$$

$$= +\ 3.0\ kN/m^2$$



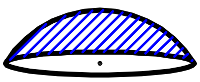
$$T_1 = T_2 = \frac{R\,Z}{2} = \frac{4.45 * 3.0}{2} = +\ 6.675\ kN/m\ \ Comp.$$

Sec. ②



$$Cos\,\phi = \frac{3.2}{4.45} \longrightarrow \boxed{\phi = 44.02^\circ}$$

$$r = R\ Sin\phi = 4.45 * Sin\ 44.02^\circ = 3.09\ m$$

$$S.A. = 2\pi * R * h$$  $$= 2\pi * 4.45 * 1.25 = 34.95\ m^2$$

$$W_\phi = g * S.A. = 3.0 * 34.95 = +104.85\ kN$$

$$T_1 = \frac{W_\phi}{2\pi r\ Sin\phi} = \frac{+104.85}{2\pi * 3.09 * Sin\ 44.02^\circ} = +\ 7.77\ kN/m\ \ Comp.$$

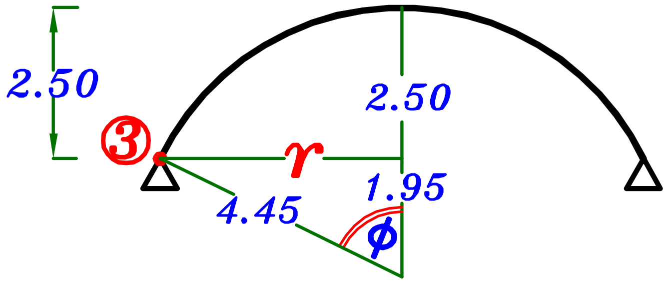
$R_1 = R_2 = R = 4.45\ m$

$Z = g\ Cos\,\phi = 3.0 * Cos\,44.02^\circ = +\,2.157\ kN/m^2$

$\because\ T_1 + T_2 = Z * R \qquad \therefore\ +7.77 + T_2 = 2.157 * 4.45$

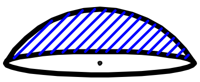
$\therefore\ T_2 = +\,1.83\ kN/m$ Comp.

Sec. 3



$Cos\,\phi = \dfrac{1.95}{4.45} \longrightarrow \boxed{\phi = 64.01^\circ}$

$r = 4.0\ m$

$S.A. = 2\pi * R * h$  $= 2\pi * 4.45 * 2.50 = 69.90\ m^2$

$W_\phi = g * S.A. = 3.0 * 69.90 = +209.7\ kN$

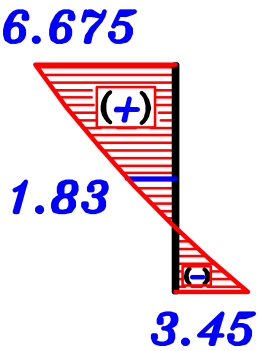
$$T_1 = \frac{W_\phi}{2\pi r\ Sin\phi} = \frac{+209.7}{2\pi * 4.0 * Sin\,64.01^\circ} = +\,9.28\ kN/m \text{ Comp.}$$

$R_1 = R_2 = R = 4.45\ m$

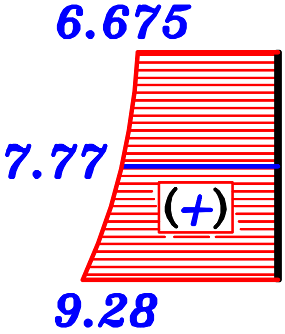
$Z = g\ Cos\,\phi = 3.0 * Cos\,64.01^\circ = +\,1.31\ kN/m^2$

$\because\ T_1 + T_2 = Z * R \qquad \therefore\ +9.28 + T_2 = 1.31 * 4.45$

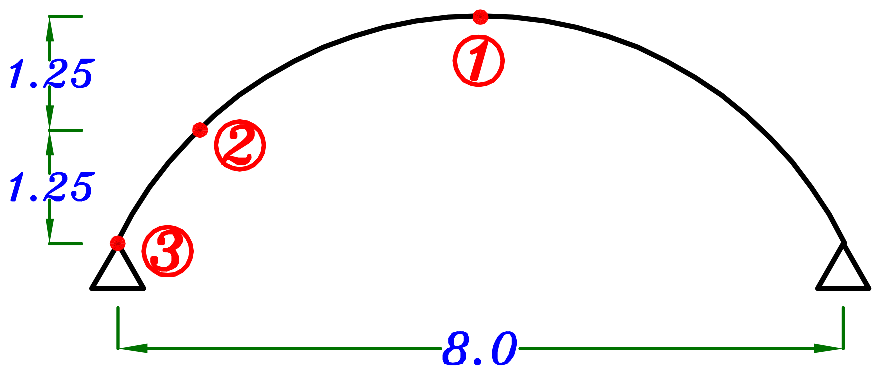
$\therefore\ T_2 = -\,3.45\ kN/m$ Ten.



T_2 Diagram (kN/m)

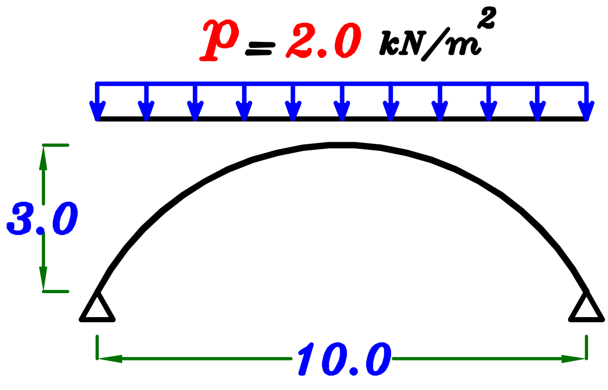


T_1 Diagram (kN/m)



Example.

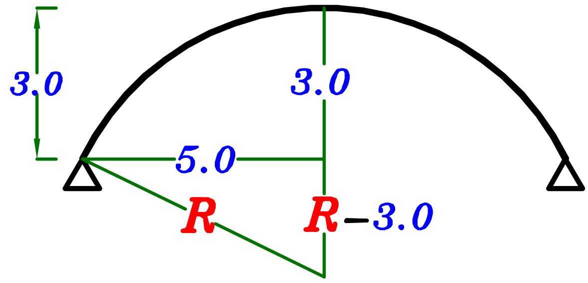
Draw T_1 & T_2 distribution (at least 3 points) on the vertical projection of the Dome due to Live load only. $p = 2.0\ kN/m^2$



$$R^2 = 5.0^2 + (R - 3.0)^2$$

$$R^2 = 25 + R^2 - 6R + 9.0$$

$$6R = 34.0 \longrightarrow \boxed{R = 5.66\ m}$$

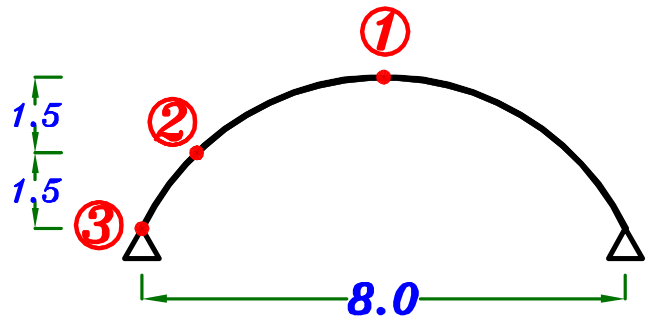


Sec. ①

$$\phi = Zero$$

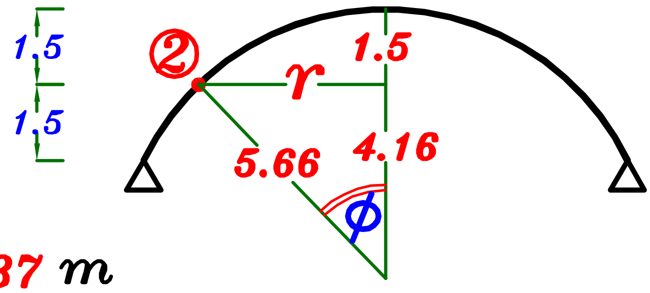
$$Z = p\ Cos^2\phi = 2.0 * Cos^2 0.0$$

$$= +\ 2.0\ kN/m^2$$



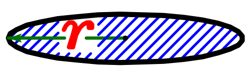
$$T_1 = T_2 = \frac{RZ}{2} = \frac{5.66 * 2.0}{2} = +\ 5.66\ \ kN/m\ \ Comp.$$

Sec. ②



$$Cos\,\phi = \frac{4.16}{5.66} \longrightarrow \boxed{\phi = 42.69^\circ}$$

$$r = R\ Sin\phi = 5.66 * Sin\ 42.69^\circ = 3.837\ m$$

Projected area $= \pi * r^2$  $= \pi * 3.837^2 = 46.25\ m^2$

$$W_\phi = p * Projected\ \ area = 2.0 * 46.25 = +92.50\ kN$$

$$T_1 = \frac{W\phi}{2\pi r\ \ Sin\phi} = \frac{+92.50}{2\pi * 3.837 * Sin\ 42.69^\circ} = +\ 5.66\ kN/m\ \ Comp.$$

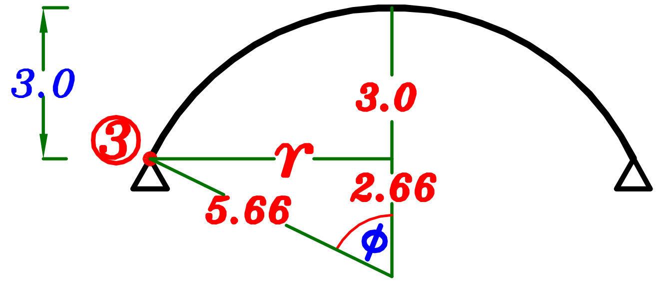
$$R_1 = R_2 = R = 5.66\ m$$

$$Z = p\,Cos^2\phi = 2.0 * Cos^2 42.69^\circ = +\ 1.08\ \ kN/m^2$$

$$\because\ T_1 + T_2 = Z * R \qquad \therefore\ +5.65 + T_2 = 1.08 * 5.66$$

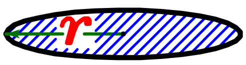
$$\therefore\ T_2 = +\ 0.46\ kN/m\ \ Comp.$$

Sec. ③



$$Cos\,\phi = \frac{2.66}{5.66} \longrightarrow \boxed{\phi = 61.96^\circ}$$

$$r = 5.0\ m$$

$$Projected\ \ area = \pi * r^2$$  $$= \pi * 5.0^2 = 78.54\ m^2$$

$$W_\phi = p * Projected\ \ area = 2.0 * 78.54 = +157.08\ \ kN$$

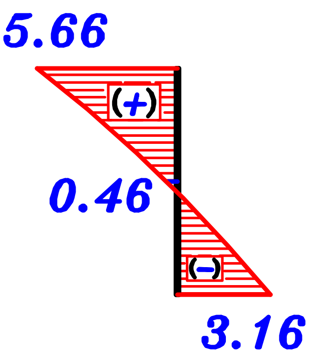
$$T_1 = \frac{W_\phi}{2\pi r\ \ Sin\phi} = \frac{+157.08}{2\pi * 5.0 * Sin\ 61.96^\circ} = +\ 5.66\ \ kN/m\ \ Comp.$$

$$R_1 = R_2 = R = 5.66\ m$$

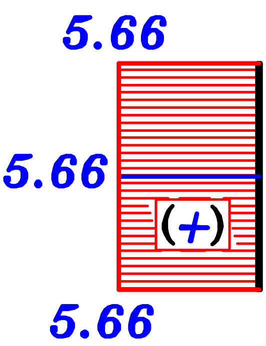
$$Z = p\,Cos^2\phi = 2.0 * Cos^2 61.96^\circ = +\ 0.442\ \ kN/m^2$$

$$\because\ T_1 + T_2 = Z * R \qquad \therefore\ +5.66 + T_2 = 0.442 * 5.66$$

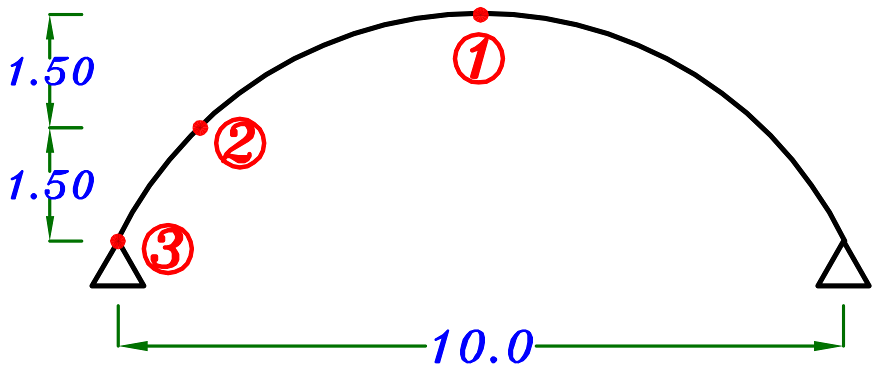
$$\therefore\ T_2 = -\ 3.16\ kN/m\ \ Ten.$$



T_2 Diagram (kN/m)

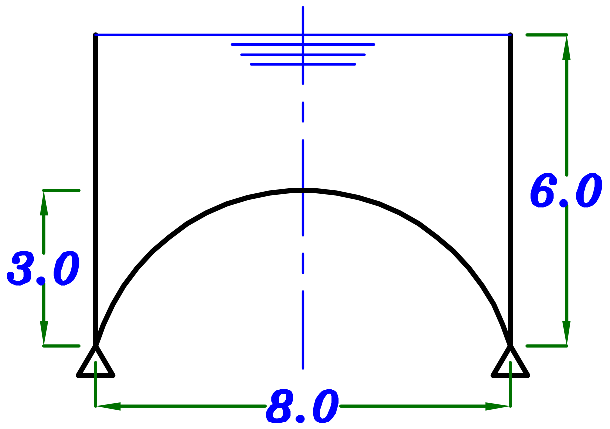


T_1 Diagram (kN/m)



Example.

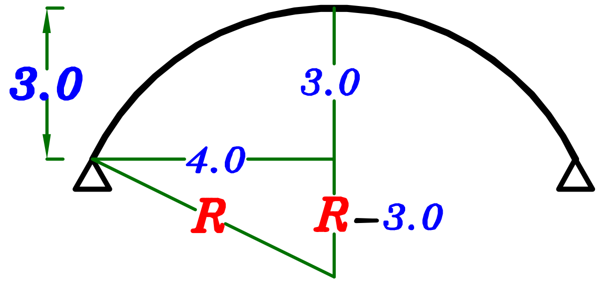
Draw T_1 & T_2 distribution on the vertical projection of the Dome due to water pressure only.



$$R^2 = 4.0^2 + (R - 3.0)^2$$

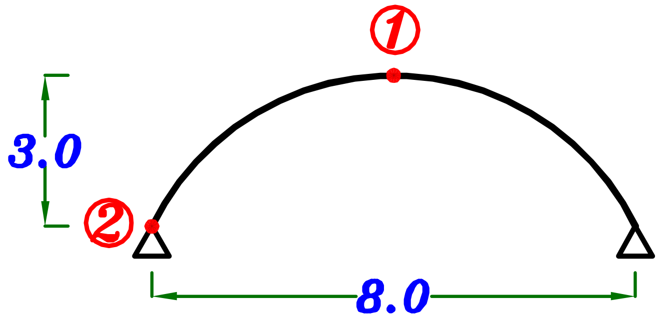
$$R^2 = 16 + R^2 - 6R + 9.0$$

$$6R = 25.0 \longrightarrow \boxed{R = 4.17\ m}$$



Sec. ①

$$\phi = Zero$$



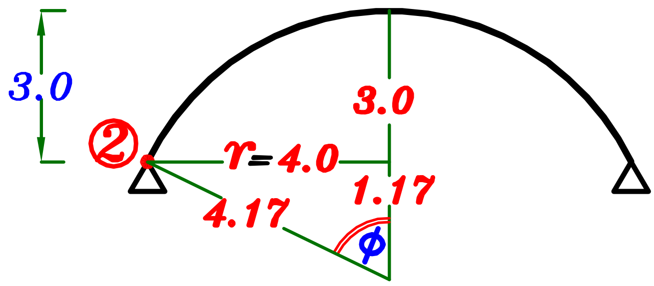
$$Z = \gamma_w * h = 10.0 * 3.0 = +\ 30\ \ kN/m^2$$

$$T_1 = T_2 = \frac{RZ}{2} = \frac{4.17 * 30}{2} = +\ 62.55\ \ kN/m\ \ Comp.$$

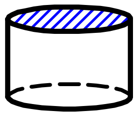
Sec. ②

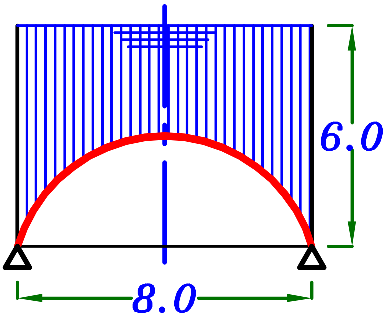
$$Cos\,\phi = \frac{1.17}{4.17} \longrightarrow \boxed{\phi = 73.70^\circ}$$

$$r = 4.0\ m$$



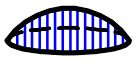
$$\text{Volume of Cylinder} = \pi * r^2 * h$$





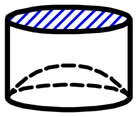
$$= \pi * 4.0^2 * 6.0 = 301.6\ m^3$$

$$\text{Volume of Dome} = \frac{\pi * h}{6}(3r^2 + h^2)$$



$$= \frac{\pi * 3.0}{6}(3 * 4.0^2 + 3.0^2) = 89.53\ m^3$$

Volume of Water



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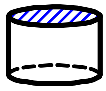
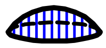




$$= 301.6 - 89.53 = 212.07\ m^3$$

$$W_\phi = \gamma_w * \text{Volume} = 10.0 * 212.07 = +2120.7\ kN$$

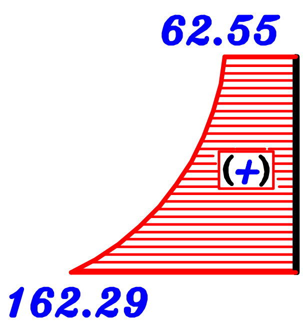
$$T_1 = \frac{W_\phi}{2\pi r\ \sin\phi} = \frac{+2120.7}{2\pi * 4.0 * \sin 73.70^\circ} = +87.91\ kN/m\ \text{Comp.}$$

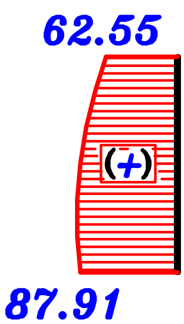
$$R_1 = R_2 = R = 4.17\ m$$

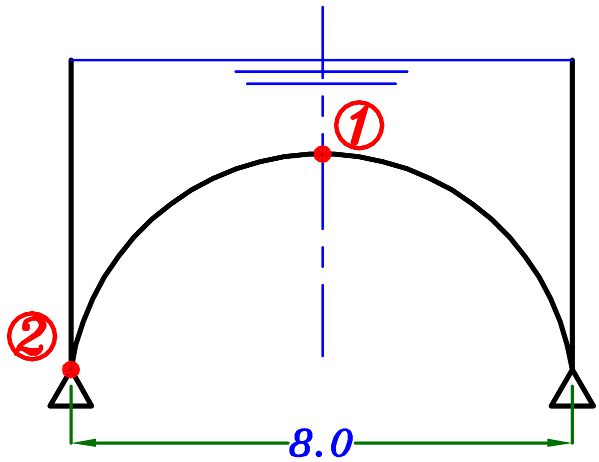
$$Z = \gamma_w * h = 10.0 * 6.0 = +60\ kN/m^2$$

$$\because T_1 + T_2 = Z * R \quad \therefore +87.91 + T_2 = 60 * 4.17$$

$$\therefore T_2 = +162.29\ kN/m\ \text{Comp.}$$





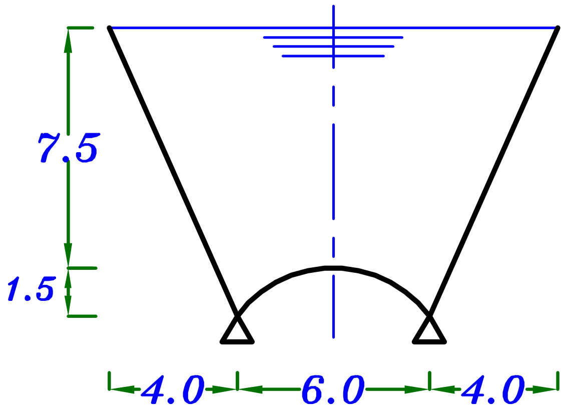


T_2 **Diagram** (kN/m) T_1 **Diagram** (kN/m)

Example.

Draw T_1 & T_2 distribution on the vertical projection. due to dead load & water pressure.

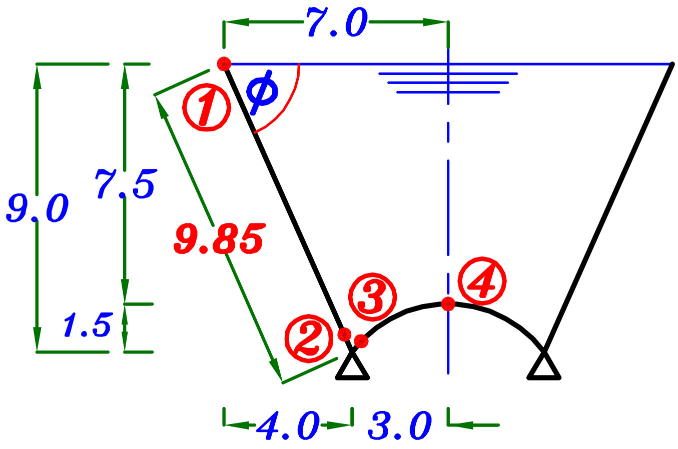
$t_s = 0.16$ m



$$\text{Deal Load} = g = t_s \, \gamma_c = 0.16 * 25 = 4.0 \;\; kN/m^2$$

For Cone

$$\tan \phi = \frac{9.0}{4.0} \longrightarrow \boxed{\phi = 66.03^\circ}$$



Sec. 1

$r = 7.0$ m

$$W_\phi = Zero \longrightarrow T_1 = Zero$$

$$Z = g \cos\phi + \gamma_w * h = 4.0 * \cos 66.03^\circ + \gamma_w * Zero = -1.62 \;\; kN/m^2$$

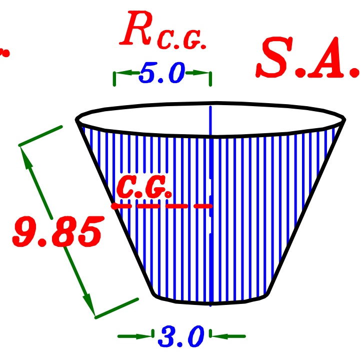
اشاره Z $(-Ve)$ لان اتجاهها خارج من المحور

$$R_2 = \frac{r}{\sin\phi} = \frac{7.0}{\sin 66.03^\circ} = 7.66 \; m$$

$$T_2 = Z * R_2 = -1.62 * 7.66 = -12.41 \;\; kN/m \;\; \text{Ten.}$$

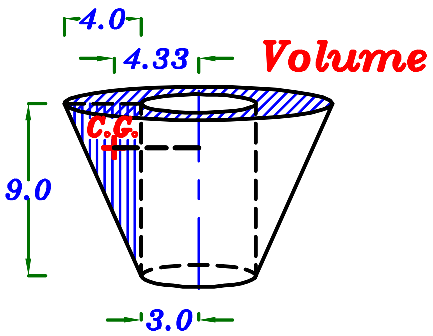
Sec. 2

$r = 3.0$ m



$$S.A. = L * 2\pi * R_{c.G.}$$

$$= 9.85 * 2\pi * 5.0 = 309.44 \; m^2$$



$$\text{Volume of water} = Area * 2\pi * R_{c.G.}$$

$$= \left(\frac{1}{2} * 4.0 * 9.0\right) * 2\pi * 4.33$$

$$= 489.71 \; m^3$$

$$W_\phi = g * S.A. + \gamma_w * Volume$$

$$= 4.0 * 309.44 + 10.0 * 489.71 = 6134.86 \; kN$$

$$T_1 = \frac{W_\phi}{2\pi r \; Sin\phi} = \frac{+6134.86}{2\pi * 3.0 * Sin \, 66.03^\circ} = +356.18 \; kN/m \quad Comp.$$

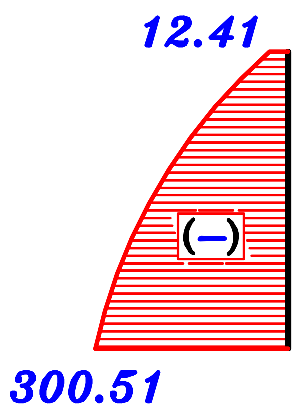
$$Z = g \, Cos\phi + \gamma_w * h = 4.0 * Cos \, 66.03^\circ + 10 * 9.0 = -91.62 \; kN/m^2$$

اشاره Z $(-Ve)$ لان اتجاهها خارج من المحور

$$R_2 = \frac{r}{Sin\phi} = \frac{3.0}{Sin \, 66.03^\circ} = 3.28 \; m$$

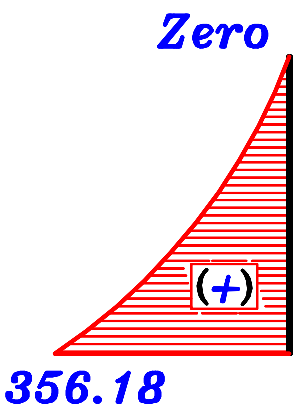
$$\because \quad T_2 = Z * R_2 = -91.62 * 3.28 = -300.51 \; kN/m \quad Comp.$$

T_1 & T_2 distribution For the Cone.



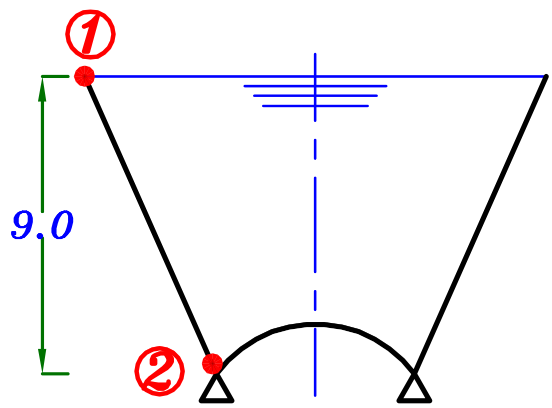
T_2

Diagram (kN/m)

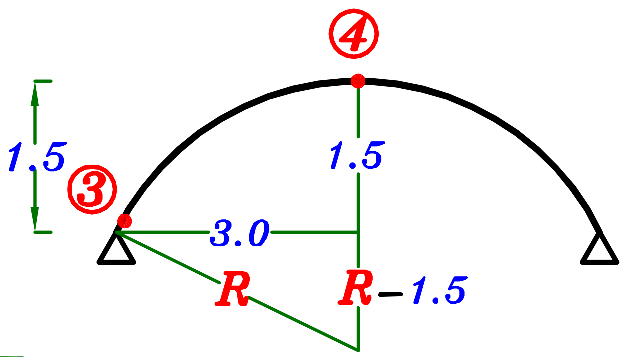


T_1

Diagram (kN/m)



Dome.



$$R^2 = 3.0^2 + (R - 1.5)^2$$

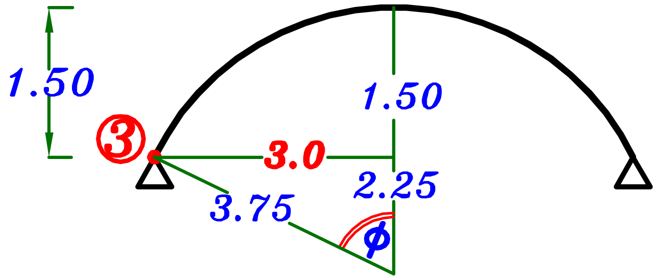
$$R^2 = 9.0 + R^2 - 3R + 2.25$$

$$3R = 11.25 \longrightarrow \boxed{R = 3.75 \; m}$$

Sec. ③

$$\cos\phi = \frac{2.25}{3.75} \longrightarrow \boxed{\phi = 53.13^\circ}$$

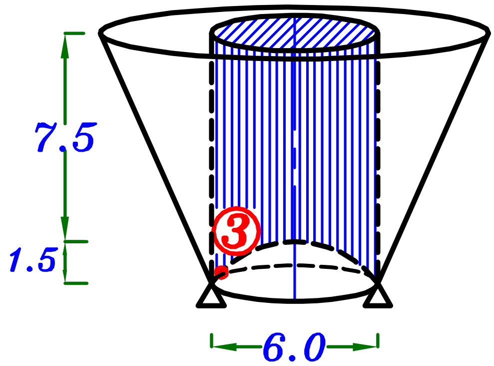
$$r = 3.0 \ m$$



$$S.A. = 2\pi * R * h = 2\pi * 3.75 * 1.50 = 35.34 \ m^2$$

$$\text{Volume of Cylinder} = \pi * r^2 * h$$

$$= \pi * 3.0^2 * 9.0 = 254.47 \ m^3$$



$$\text{Volume of Dome} = \frac{\pi * h}{6}(3r^2 + h^2)$$

$$= \frac{\pi * 1.5}{6}(3 * 3.0^2 + 1.5^2) = 22.97 \ m^3$$

$$\text{Volume of Water} = 254.47 - 22.97 = 231.5 \ m^3$$

$$W_\phi = g * S.A. + \gamma_w * \text{Volume}$$

$$= 4.0 * 35.34 + 10.0 * 231.5 = 2456.36 \ kN$$

$$T_1 = \frac{W_\phi}{2\pi r \sin\phi} = \frac{+2456.36}{2\pi * 3.0 * \sin 53.13^\circ} = +162.90 \ kN/m \ \text{Comp.}$$

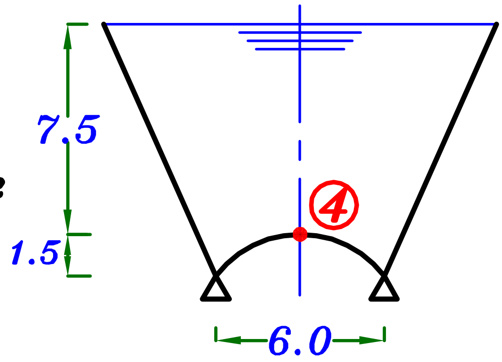
$$R_1 = R_2 = R = 3.75 \ m$$

$$Z = g\cos\phi + \gamma_w * h = 4.0 * \cos 53.13^\circ + 10 * 9.0 = +92.40 \ kN/m^2$$

$$\because T_1 + T_2 = Z * R \qquad \therefore +162.90 + T_2 = 92.40 * 3.75$$

$$\therefore T_2 = +183.6 \ kN/m \ \text{Comp.}$$

Sec. 4 $\quad \phi = \text{Zero}$

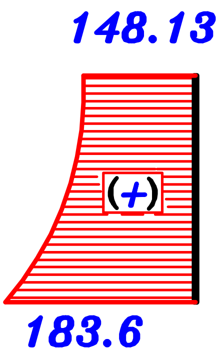


$$Z = g \cos\phi + \gamma_w * h$$

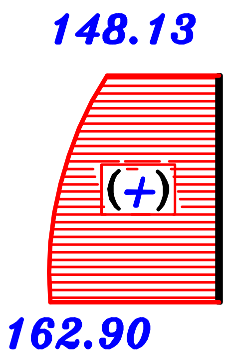
$$= 4.0 * \cos 0.0 + 10 * 7.5 = +79.0 \ kN/m^2$$

$$T_1 = T_2 = \frac{RZ}{2} = \frac{3.75 * 79.0}{2} = +148.13 \ kN/m \ \text{Comp.}$$

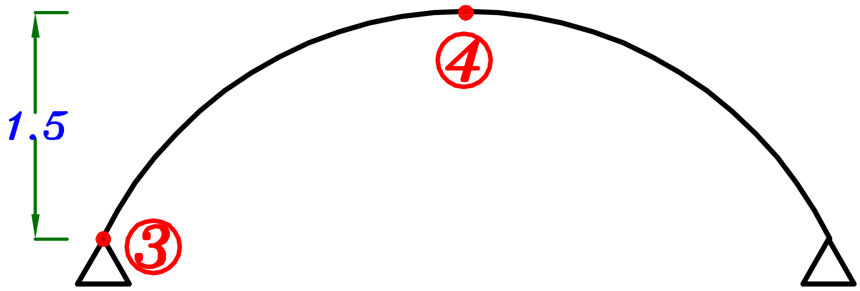
T_1 & T_2 distribution For the Dome.



T_2
Diagram (kN/m)



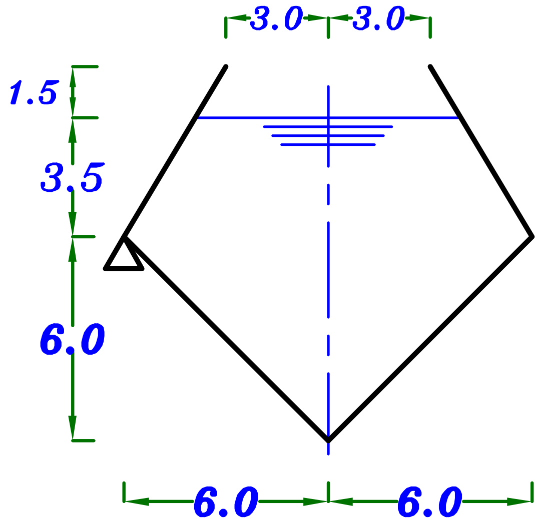
T_1
Diagram (kN/m)



Example.

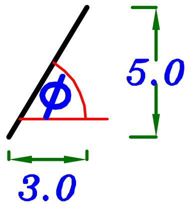
Draw T_1 & T_2 distribution on the vertical projection. due to dead load & water pressure.

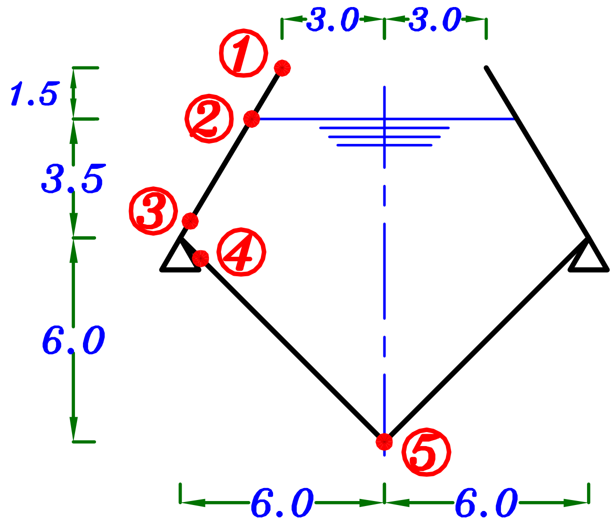
$t_s = 0.20$ m



$$\text{Deal Load} = g = t_s \gamma_c = 0.20 * 25 = 5.0 \ kN/m^2$$

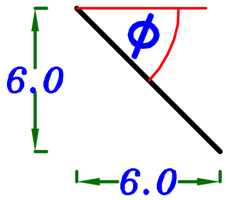
First Cone.





$$\tan\phi = \frac{5.0}{3.0} \longrightarrow \boxed{\phi = 59.04^\circ}$$

Second Cone.



$$\tan\phi = \frac{6.0}{6.0} \longrightarrow \boxed{\phi = 45.0^\circ}$$

Sec. 1 $\quad r = 3.0$ m

$$W_\phi = Zero \longrightarrow T_1 = Zero$$

$$Z = g \cos\phi = 5.0 * \cos 59.04^\circ = +2.572 \ kN/m^2$$

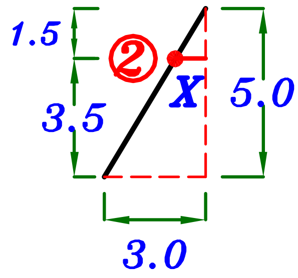
$$R_2 = \frac{r}{\sin\phi} = \frac{3.0}{\sin 59.04^\circ} = 3.50 \ m$$

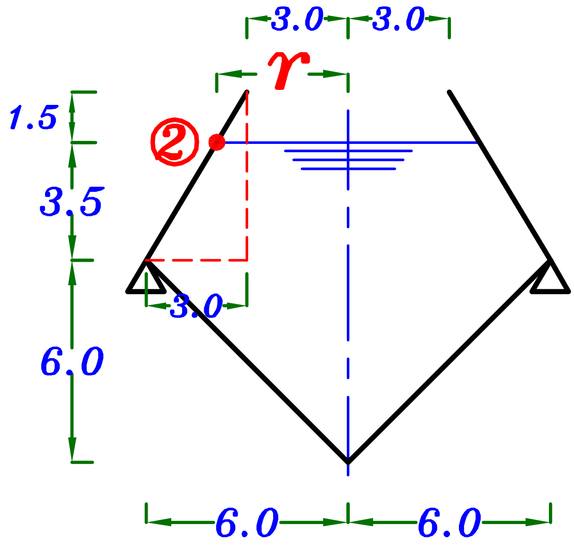
$$T_2 = Z * R_2 = +2.572 * 3.50 = +9.0 \ kN/m \ \text{Comp.}$$

Sec. 2

$$\frac{1.5}{5.0} = \frac{X}{3.0} \longrightarrow X = 0.9\, m$$

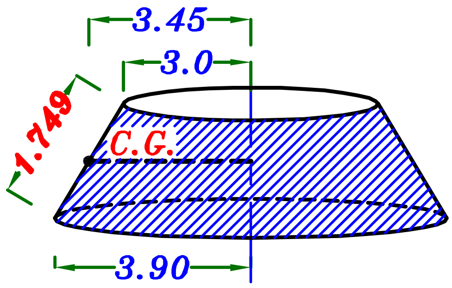
$$r = 3.0 + 0.9 = 3.90\, m$$





$$S.A. = L * 2\pi * R_{C.G.}$$

$$= 1.749 * 2\pi * 3.45 = 37.91\ m^2$$



$$W_\phi = g * S.A. = 5.0 * 37.91 = +189.55\ kN$$

$$T_1 = \frac{W_\phi}{2\pi r\ \sin\phi} = \frac{+189.55}{2\pi * 3.90 * \sin 59.04^\circ} = +9.02\ kN/m\ \text{Comp.}$$

$$Z = g \cos\phi = 5.0 * \cos 59.04^\circ = +2.572\ kN/m^2$$

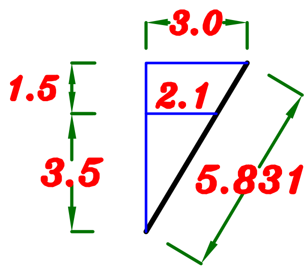
$$R_2 = \frac{r}{\sin\phi} = \frac{3.90}{\sin 59.04^\circ} = 4.548\ m$$

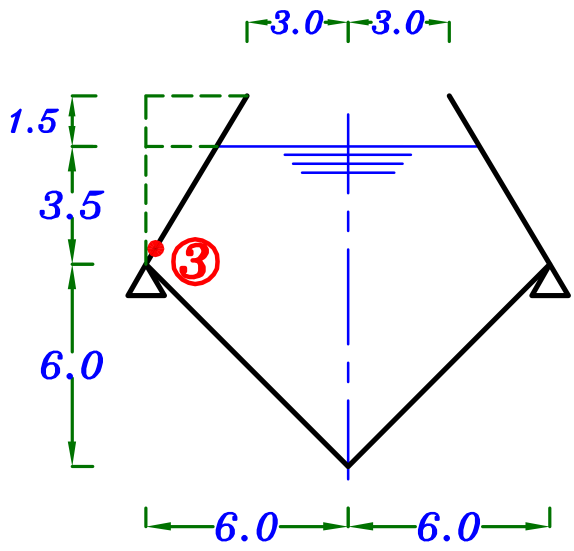
$$T_2 = Z * R_2 = 2.572 * 4.548 = +11.70\ kN/m\ \text{Comp.}$$

Sec. 3

$$r = 6.0\ m$$

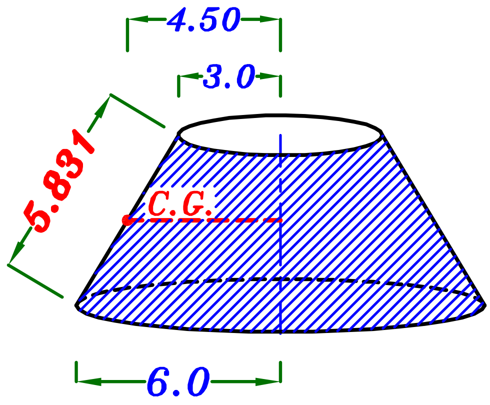
$$\phi = 59.04^\circ$$



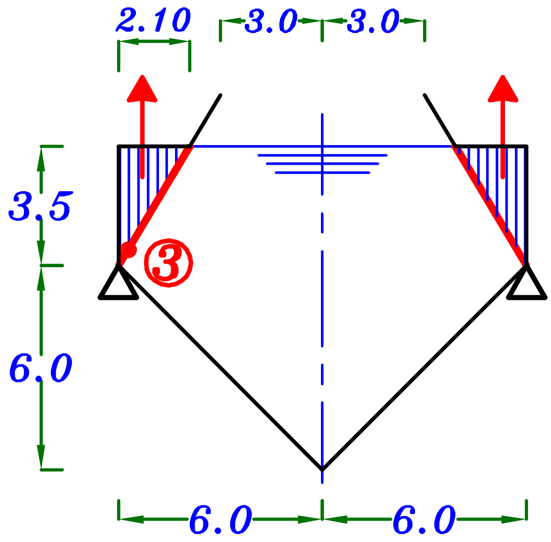


$$S.A. = L * 2\pi * R_{C.G.}$$

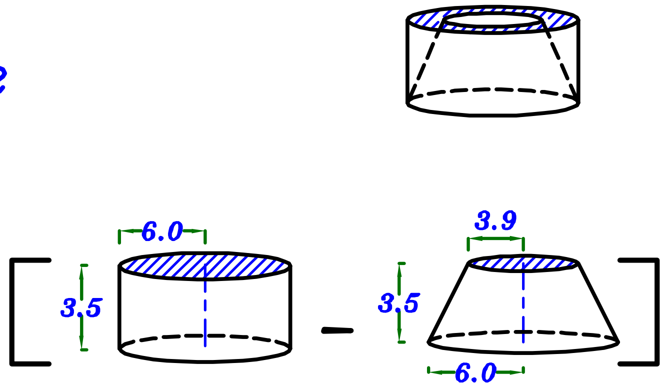
$$= 5.831 * 2\pi * 4.50 = 164.86\ m^2$$



Volume



Volume of



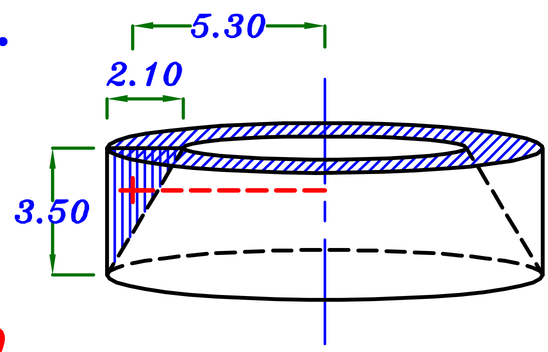
$$Volume = \left[\pi r^2 * h - \frac{\pi h}{3}(a^2 + b^2 + ab)\right]$$

$$= \left[\pi * 6.0^2 * 3.5 - \frac{\pi * 3.5}{3}\left(3.9^2 + 6.0^2 + 3.9 * 6.0\right)\right]$$

$$= 122.38\ m^3$$

Or we can get the volume From.

$$Volume = Area * 2\pi * R_{c.G.}$$



$$Volume = \left(\frac{1}{2} * 2.10 * 3.5\right) * 2\pi * 5.30$$

$$= 122.38\ m^3$$

$$W_\phi = g * S.A. \downarrow - \gamma_w * Volume \uparrow$$

$$= 5.0 * 164.86 - 10.0 * 122.38 = -399.5 \ kN \uparrow$$

تم طرح القيمتين من بعضهما لان وزن السطح $(g * S.A.)$ يؤثر رأسيا لاسفل بينما ضغط الماء $(\gamma_w * Volume)$ يؤثر رأسيا لاعلى .

$$T_1 = \frac{W_\phi}{2\pi r \ Sin\phi} = \frac{-399.5}{2\pi * 6.0 * Sin\, 59.04^\circ} = -12.36 \ \ kN/m \ \ Comp.$$

$$Z = g\, Cos\phi \searrow - \gamma_w * h \nwarrow$$

$$= 5.0 * Cos\, 59.04^\circ - 10 * 3.5 = -32.43 \ \ kN/m^2$$

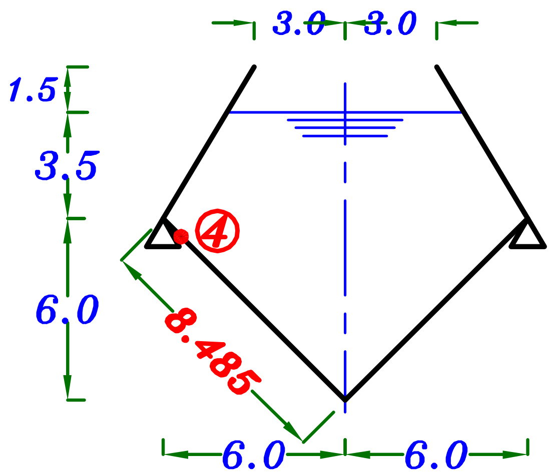
$$R_2 = \frac{r}{Sin\phi} = \frac{6.0}{Sin\, 59.04^\circ} = 7.0 \ m$$

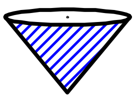
$$\because \ T_2 = Z * R_2 = -32.43 * 7.0 = -227.0 \ kN/m \ \ Ten.$$

Sec. 4

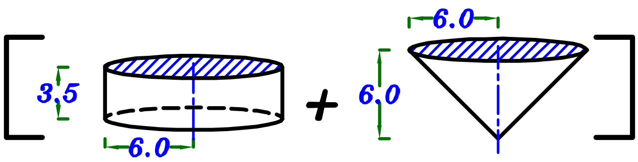
$r = 6.0 \ m$

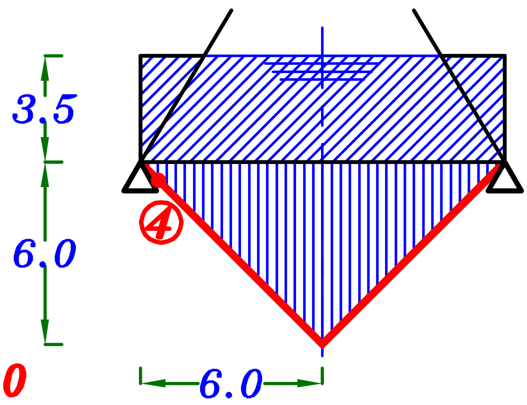
$\phi = 45.0^\circ$



$S.A. = \pi * r * L$ 

$$= \pi * 6.0 * 8.485 = 159.93 \ m^2$$

Volume 



$$Volume = \pi r^2 * h + \frac{1}{3} * \pi * r^2 * h$$

$$= \pi * 6.0^2 * 3.5 + \frac{1}{3} * \pi * 6.0^2 * 6.0$$

$$= 622.03 \ \ m^3$$

$$W_\phi = g * S.A. + \gamma_w * Volume$$

$$= 5.0 * 159.93 + 10.0 * 622.03 = -7019.95 \ kN$$

اشاره W_ϕ $(-Ve)$ لان اتجاهها خارج من ال Support

$$T_1 = \frac{W_\phi}{2\pi r \ Sin\phi} = \frac{-7019.95}{2\pi * 6.0 * Sin\ 45^\circ} = -263.36 \ kN/m \ Ten.$$

$$Z = g \ Cos\phi + \gamma_w * h$$

$$= 5.0 * Cos\ 45^\circ + 10 * 3.5 = -38.53 \ kN/m^2$$

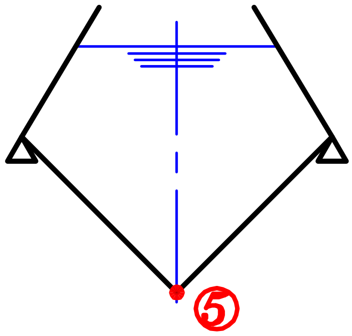
اشاره Z $(-Ve)$ لان اتجاهها خارج من المحور

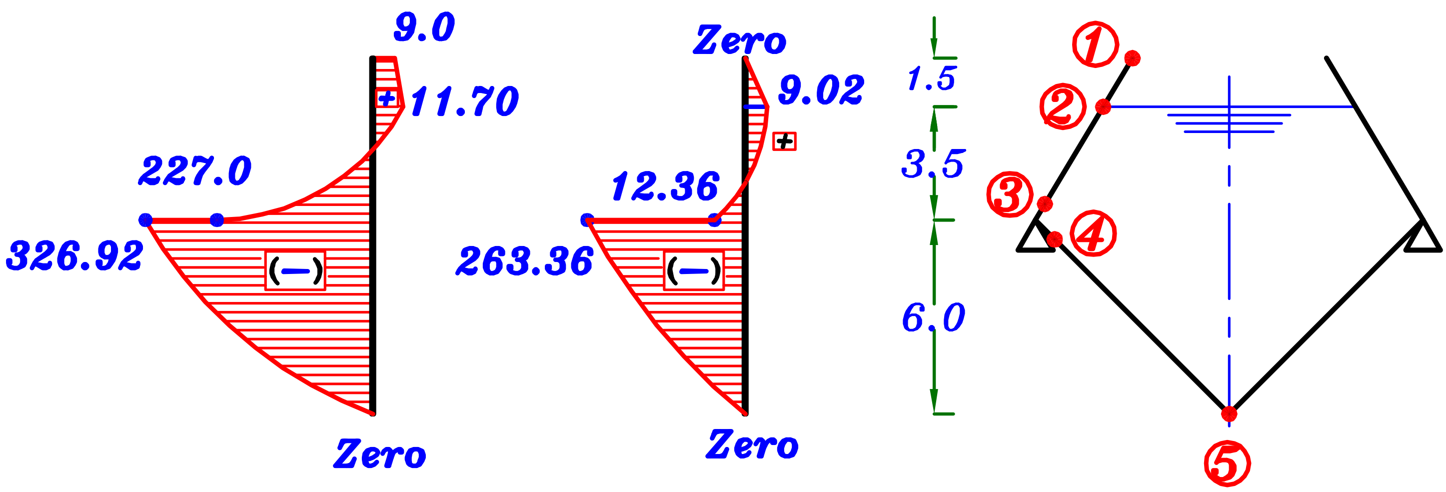
$$R_2 = \frac{r}{Sin\phi} = \frac{6.0}{Sin\ 45^\circ} = 8.485 \ m$$

$$\because \ T_2 = Z * R_2 = -38.53 * 8.485 = -326.92 \ kN/m \ Ten.$$

Sec. ⑤ Vertex of the Cone.

$$T_1 = T_2 = Zero$$





T_2 Diagram (kN/m) T_1 Diagram (kN/m)

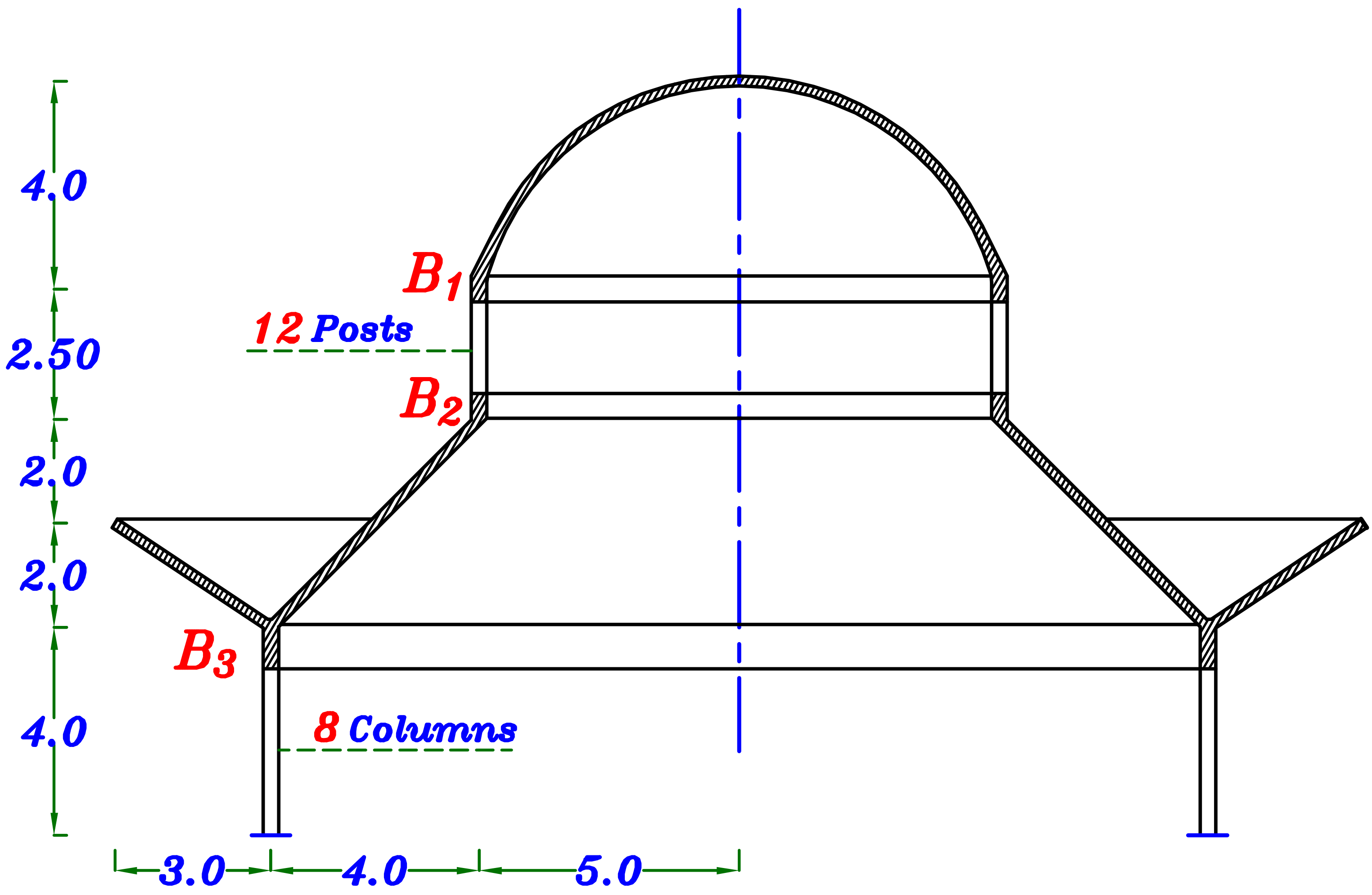
Example.

For the shown surface of revolution, It is required to:

Calculate the internal Forces at the critical sections.

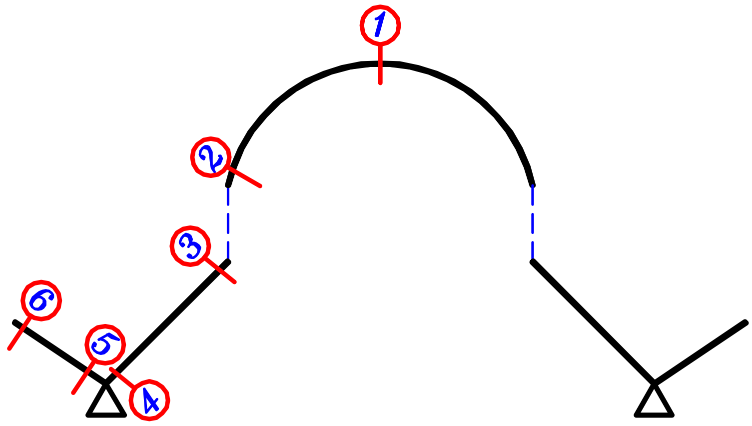
Given:

F.C. = 1.0 kN/m^2 , L.L. = 0.50 kN/m^2 (H.P.)



Solution.

Choose $t_s = 100\ mm \longrightarrow 140\ mm$



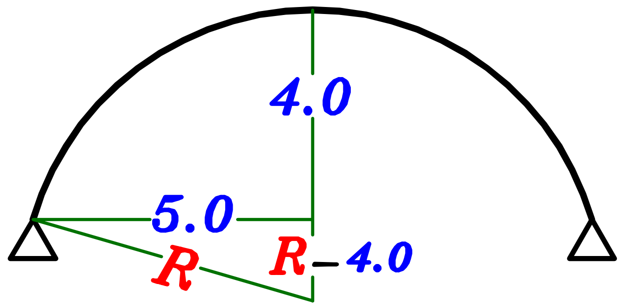
Take $\boxed{t_s = 100\ mm}$

Loads.

$g_s = t_s\,\gamma_c + F.C. = 0.10 * 25 + 1.0 = 3.5\ kN/m^2$

$p_s = 0.5\ kN/m^2$

For the Dome.



$R^2 = 5.0^2 + (R - 4.0)^2$

$\cancel{R^2} = 25 + \cancel{R^2} - 8.0\,R + 16.0$

$8.0\ R = 41.0 \longrightarrow \boxed{R = 5.125\,m}$

Sec. 1 Dome Vertex $\phi = Zero$

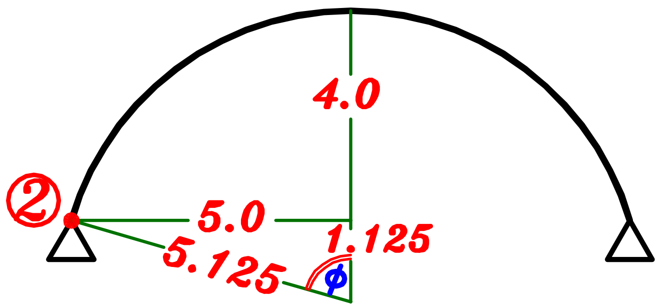
$Z = g\ Cos\,\phi + p\ Cos^2\phi$

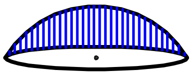
$= 3.5 * Cos\,0.0 + 0.5 * Cos^2\,0.0 = +4.0\ kN/m^2$

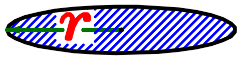
$(T_1)_1 = (T_2)_1 = \dfrac{R\,Z}{2} = \dfrac{5.125 * 4.0}{2} = +\ 10.25\ kN/m$ Comp.

Sec. 2

$Sin\,\phi = \dfrac{5.0}{5.125} \longrightarrow \boxed{\phi = 77.32^\circ}$



$S.A. = 2\pi * R * h$  $= 2\pi * 5.125 * 4.0 = 128.80\ m^2$

$Projected\ area = \pi * r^2$  $= \pi * 5.0^2 = 78.54\ m^2$

$W_\phi = g * S.A. + p * Projected\ area$

$= 3.5 * 128.80 + 0.5 * 78.54 = +490.07\ kN$

$$(T_1)_2 = \frac{W_\phi}{2\pi r\ Sin\phi} = \frac{+490.07}{2\pi * 5.0 * Sin\ 77.32^\circ} = +15.99\ kN/m\ \ Comp.$$

$R_1 = R_2 = R = 5.125\ m$

$Z = g\ Cos\phi + p\ Cos^2\phi$

$= 3.5 * Cos\ 77.32 + 0.5 * Cos^2\ 77.32 = +0.792\ kN/m^2$

$\because T_1 + T_2 = Z * R \qquad \therefore +15.99 + T_2 = 0.792 * 5.125$

$\therefore (T_2)_2 = -11.93\ kN/m\ \ Ten.$

For beams B_1 & B_2 $\qquad L = \dfrac{2\pi r}{n} = \dfrac{2 * \pi * 5}{12} = 2.61\ m$

$t = \dfrac{L}{12} + 0.2\ m = \dfrac{2.61}{12} + 0.2 = 0.41 = 0.45\ m$

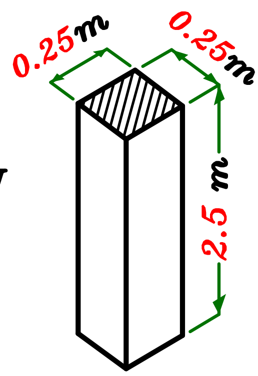
Take B_1 & B_2 (250*450)

$o.w._{(B_1 \& B_2)} = b * t * \gamma_c = 0.25 * 0.45 * 25 = 2.81\ kN/m$

$T.W. = Total\ Weight_{(B_1 \& B_2)} = o.w. * 2\pi r = 2.81 * 2\pi * 5.0 = 88.27\ kN$

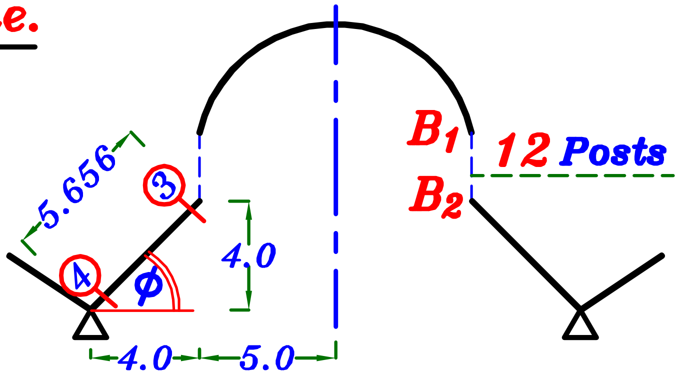
Take Post (0.25*0.25*2.50)

$o.w._{(Post)} = 0.25 * 0.25 * 2.50 * 25 = 3.90\ kN$



For the Cone under the Dome.

$$\tan\phi = \frac{4.0}{4.0} \longrightarrow \boxed{\phi = 45.0^\circ}$$



Sec. 3 $\quad r = 5.0\ m$

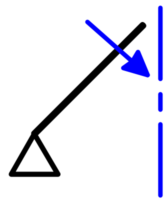
$$W_\phi = W_\phi{}_{(Sec.2)} + T.W._{(B_1)} + T.W._{(B_2)} + n * o.w._{(Post)}$$

$$W_\phi = 490.07 + 88.27 + 88.27 + 12 * 3.90 = +713.41\ kN$$

$$(T_1)_3 = \frac{W_\phi}{2\pi r\ \sin\phi} = \frac{+713.41}{2\pi * 5.0 * \sin 45^\circ} = +\ 32.11\ kN/m\ \ Comp.$$

$$Z = g\ \cos\phi + p\ \cos^2\phi = 3.5 * \cos 45 + 0.5 * \cos^2 45 = +2.725\ kN/m^2$$

اشاره Z (+Ve) لان اتجاهها داخل الى المحور

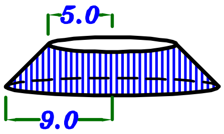


$$R_2 = \frac{r}{\sin\phi} = \frac{5.0}{\sin 45^\circ} = 7.071\ m$$

$$\because\ (T_2)_3 = Z * R_2 = +2.725 * 7.071 = +\ 19.27\ kN/m\ \ Comp.$$

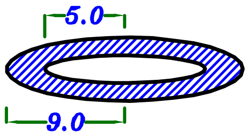
Sec. 4 $\quad r = 9.0\ m$

$$S.A. = \pi * L\ (a+b)$$



$$= \pi * 5.656 * (9.0 + 5.0) = 248.76\ m^2$$

$$\text{Projected area} = \pi * (r_1^2 - r_2^2)$$



$$= \pi * (9.0^2 - 5.0^2) = 175.93\ m^2$$

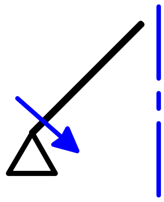
$$W_\phi = W_\phi{}_{(Sec.3)} + g * S.A. + p * \text{Projected area}$$

$$= 713.41 + 3.5 * 248.76 + 0.5 * 175.93 = +1672.03\ kN$$

$$(T_1)_4 = \frac{W_\phi}{2\pi r\ \sin\phi} = \frac{+1672.03}{2\pi * 9.0 * \sin 45^\circ} = +\ 41.81\ kN/m\ \ Comp.$$

$$Z = g\,\cos\phi + p\,\cos^2\phi = 3.5 * \cos 45 + 0.5 * \cos^2 45 = +2.725\ \text{kN/m}^2$$

اشاره Z $(+Ve)$ لان اتجاهها داخل الى المحور

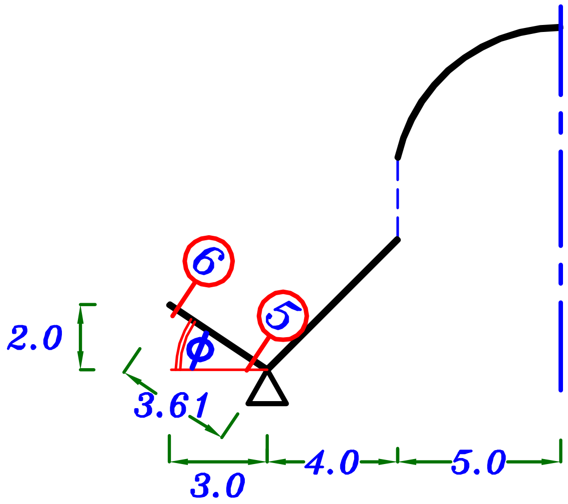


$$R_2 = \frac{r}{\sin\phi} = \frac{9.0}{\sin 45^\circ} = 12.727\ m$$

$$\because\ (T_2)_4 = Z * R_2 = +2.725 * 12.727 = +34.68\ \text{kN/m}\ \ \textbf{Comp.}$$

For the outer Cone.

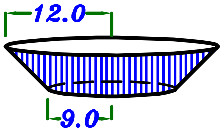
$$\tan\phi = \frac{2.0}{3.0} \longrightarrow \boxed{\phi = 33.69^\circ}$$



Sec. 5

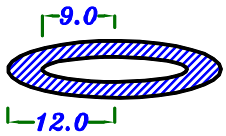
$$r = 9.0\ m$$

$$S.A. = \pi * L\,(a+b)$$



$$= \pi * 3.61 * (12.0 + 9.0) = 238.16\ m^2$$

$$\text{Projected area} = \pi * (r_1^2 - r_2^2)$$



$$= \pi * (12.0^2 - 9.0^2) = 197.92\ m^2$$

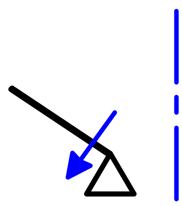
$$W_\phi = g * S.A. + p * \text{Projected area}$$

$$= 3.5 * 238.16 + 0.5 * 197.92 = +932.52\ \text{kN}$$

$$(T_1)_5 = \frac{W_\phi}{2\pi r\,\sin\phi} = \frac{+932.52}{2\pi * 9.0 * \sin 33.69} = +29.728\ \text{kN/m}\ \ \textbf{Comp.}$$

$$Z = g\,\cos\phi + p\,\cos^2\phi = 3.5 * \cos 33.69 + 0.5 * \cos^2 33.69 = -3.26\ \text{kN/m}^2$$

اشاره Z $(-Ve)$ لان اتجاهها خارج من المحور



$$R_2 = \frac{r}{\sin\phi} = \frac{9.0}{\sin 33.69} = 16.22\ m$$

$$\because\ (T_2)_5 = Z * R_2 = -3.26 * 16.22 = -52.87\ \text{kN/m}\ \ \textbf{Ten.}$$

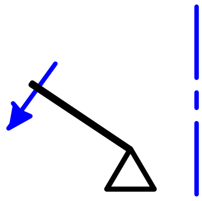
Sec. ⑥

$r = 12.0\ m$

$W_\phi = Zero \longrightarrow (T_1)_6 = Zero$

$$Z = g \cos\phi + p \cos^2\phi = 3.5 * \cos 33.69 + 0.5 * \cos^2 33.69 = -3.26\ kN/m^2$$

$$R_2 = \frac{r}{\sin\phi} = \frac{12.0}{\sin 33.69^\circ} = 21.63\ m$$



$$(T_2)_6 = Z * R_2 = -3.26 * 21.63 = -70.51\ kN/m \quad Ten.$$

Steps of Design of Sufrace of Revolution.

يتم تصميم و عمل Check لكل سطح على حده و لا علاقه له بالاسطح الاخرى مادام يوجد بينهم ركائز (Supports)

1- Choose (t_s).

يتم اختيار قيمه لل (t_s) بحيث لا تقل عن ($t_{s\,min}$)

– For ordinary sections $t_{s\,min} = 80\ mm$

Choose $t_s = 100\ mm \longrightarrow 140\ mm$

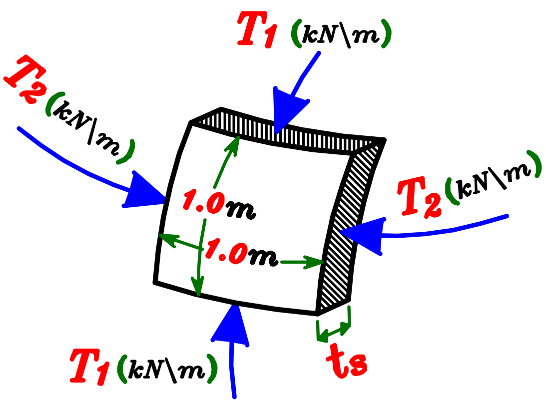
يفضل أن نختار (t_s)

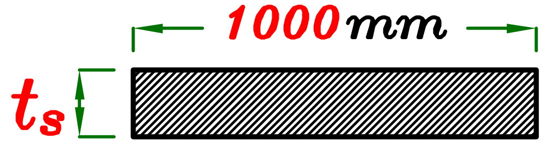
– For water sections للاسطح المعرضه مباشره للماء

Choose $t_s = 160\ mm \longrightarrow 240\ mm$

$t_{s\,min} = 160\ mm$

2- Check Compression Stresses.





شكل القطاع المعرض ل T_2 او T_1

$A_c = 1000 * t_s \quad mm^2$

يتم عمل Check Compression Stresses لتحديد اذا ما كانت الخرسانه ستتحمل ال Compression Stresses المؤثره عليها أم لا .

و يكون ال Check باحدى الطريقتين :

١- بأستخدام طريقه Working Method (مفضله)

٢- بأستخدام طريقه Ultimate Limits Method

1- Check using Working Method.

نحسب (T_{max}) و هى أكبر Compression Force على السطح سواء T_1 او T_2

و تكون هذه القوى woking Forces و يجب مراعاه أن نحدد (T_{max}) لكل سطح على حده .

$$\text{Actual working Compression Stress} = \frac{T_{max}}{A_c} = \frac{T_{max}}{1000 * t_s} \quad (N/mm^2)$$

$$\text{Allowable working Compression Stress} = \frac{F_{co}}{2}$$

F_{cu} (N/mm^2)	20	25	30	35	40
F_{co} (N/mm^2)	5.0	6.0	7.0	8.0	9.0

Egyptian Code
Page (5-2)

و نقسم قيمه F_{co} على 2 حتى نضمن عدم حدوث buckling للاسطح القشريه .

IF Actual working Stress $\leqslant$ Allowable working Stress $\longrightarrow$ (t_s) is o.k.

IF Actual working Stress $>$ Allowable working Stress $\longrightarrow$ increase (t_s)

2- Check using Ultimate Limits Method.

نستخدمها فقط اذا كنا لا نعرف قيمه F_{co}

Get $T_{U max} = 1.5 * T_{max}$

$$\text{Actual U.L. Compression Stress} = \frac{T_{U\,max}}{A_c} = \frac{T_{U\,max}}{1000 * t_s} \quad (N/mm^2)$$

$$\text{Allowable U.L. Compression Stress} = \frac{0.35\, F_{cu}}{2}$$

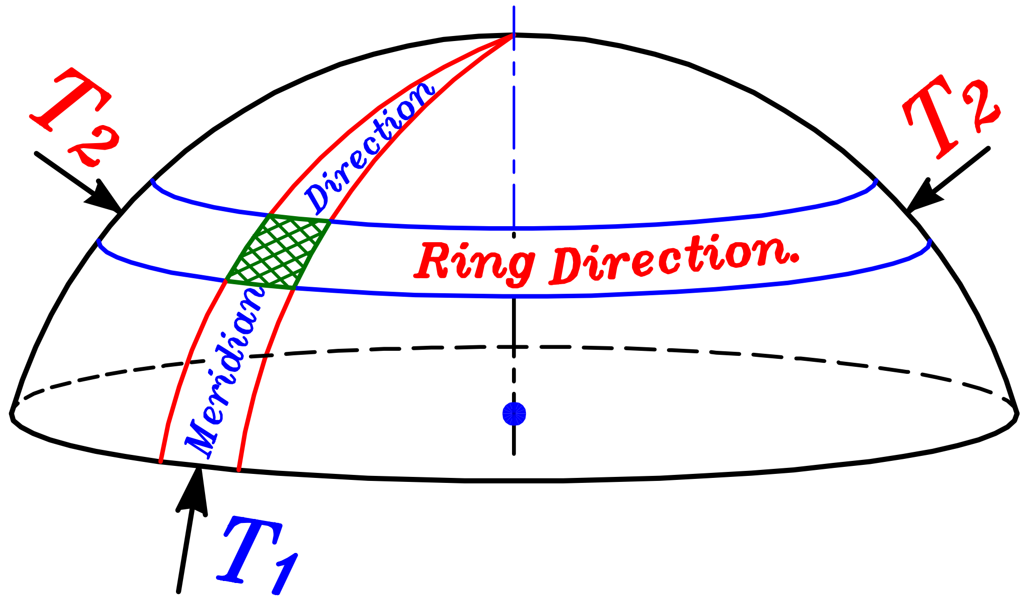
و نقسم قيمه $0.35\, F_{cu}$ على 2 حتى نضمن عدم حدوث buckling للاسطح القشريه .

IF Actual U.L. Stress $\leqslant$ Allowable U.L. Stress $\longrightarrow$ (t_s) is o.k.

IF Actual U.L. Stress $>$ Allowable U.L. Stress $\longrightarrow$ increase (t_s)

أنواع الإجهادات	المصطلحات	إجهادات التشغيل وفقاً لرتب الخرسانة حسب مقاومتها المميزة للمكعب القياسي بعد ٢٨ يوماً (ن/مم^2)			
مقاومة الخرسانة المميزة (الرتبة)	f_{cu}	18	20	25	30
الضغط المحوري ($e=e_{min}$)	f_{co}	4.5	5	6	7
الانحناء أو الضغط كبير اللامركزية	f_c	7.0	8.0	9.5	10.5
القص					
مقاومة الخرسانة للقص					
بدون تسليح في البلاطات و القواعد	q_c	0.7	0.8	0.9	0.9
بدون تسليح في الأعضاء الأخرى	q_c	0.5	0.6	0.7	0.7
وجود تسليح جذعــى فــى جميــع الأعضاء (القص واللي معا)	q_2	1.5	1.7	1.9	2.1
القص الثاقب	q_{cp}	0.7	0.8	0.9	1.0
الصلب الفولاذ					
1-صلب طري 240/350	f_s	140	140	140	140
2- صلب 280/450		160	160	160	160
3-صلب 360/520		200	200	200	200
4-صلب 400/600		220	220	220	220
5-الشبك الملحوم 450/520 أملس		160	160	160	160
ذو النتوءات أو ذو العضات		220	220	220	220

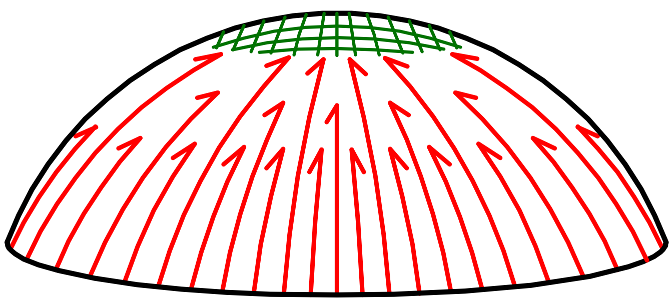
Reinforcement of Surface of Revolution.



يتم تحديد قيمه التسليح فى الاتجاهين :

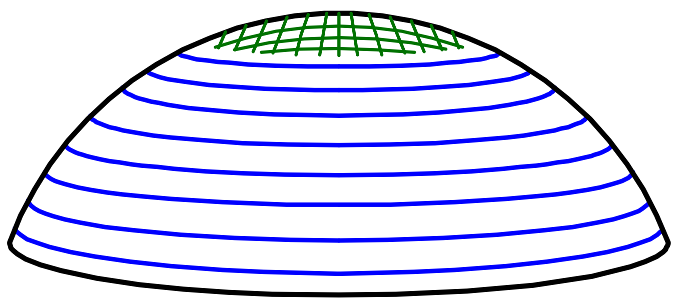
١- تسليح فى اتجاه القوى T_1 Meridian Direction

٢- تسليح فى اتجاه القوى T_2 Ring Direction



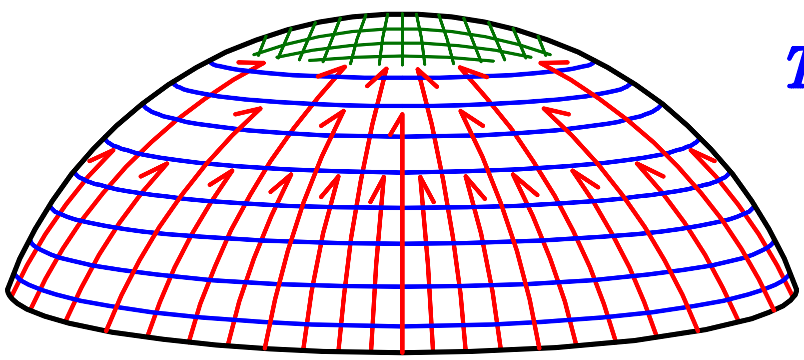
T_1 RFT.

Meridian RFT.



T_2 RFT.

Ring RFT.



Total RFT.

T_1 & T_2 RFT.

$a-$ IF all values of T_1 & T_2 are compression.

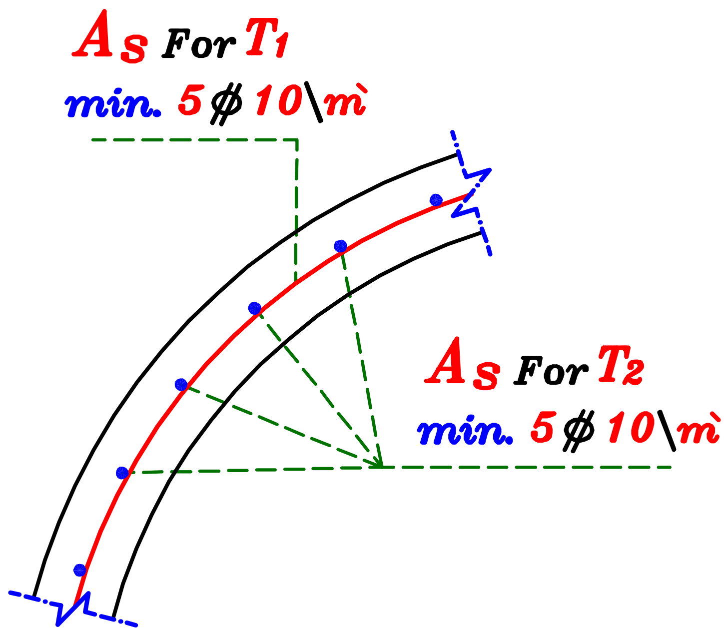
We usually use min. RFT.

– IF $t_s < 100\ mm$ use Single mesh of RFT.

$A_{s\,min.} = 0.30\%\ A_c$

$\nless 5\phi 8 \backslash m'$ For st. 240/350

$\nless 5\phi 10 \backslash m'$ For st. 360/520

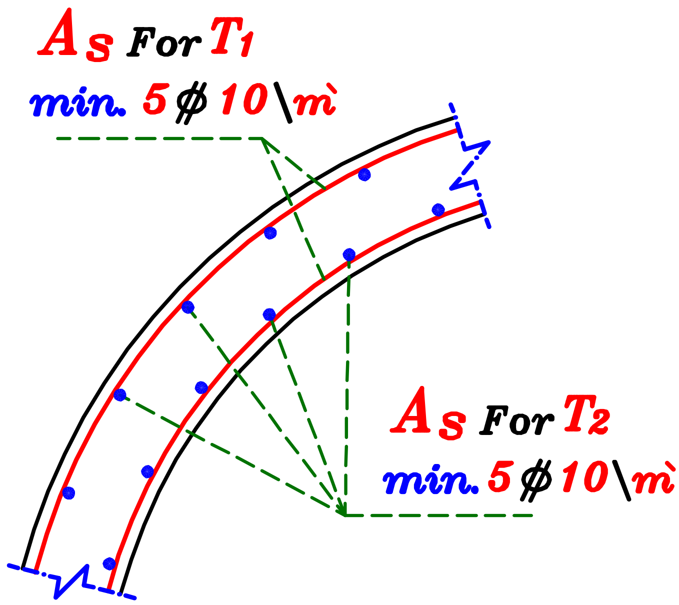


– IF $t_s \geq 100\ mm$ use Double mesh of RFT.

$A_{s\,min.} \backslash Side = 0.20\%\ A_c$

$\nless 5\phi 8 \backslash m'$ For st. 240/350

$\nless 5\phi 10 \backslash m'$ For st. 360/520



b – IF T_1 or T_2 is Tension.

IF T_1 Tension $\xrightarrow{Get}$ $T_{1\,(U.L.)} = 1.5 * T_1$

$$\boxed{A_{s\,(T_1)} = \frac{T_{1\,(U.L.)}}{F_y \backslash \gamma_s}}$$

$\nless 5\phi 8 \backslash m'$ For st. 240/350

$\nless 5\phi 10 \backslash m'$ For st. 360/520

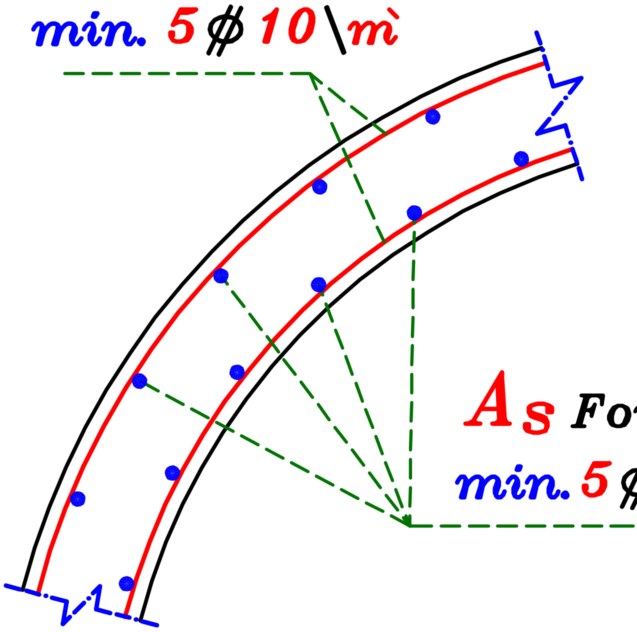
IF T_2 Tension $\xrightarrow{Get}$ $T_{2\,(U.L.)} = 1.5 * T_2$

$$\boxed{A_{s\,(T_2)} = \frac{T_{2\,(U.L.)}}{F_y \backslash \gamma_s}}$$

$\nless 5\phi 8 \backslash m'$ For st. 240/350

$\nless 5\phi 10 \backslash m'$ For st. 360/520

يجب أن يكون التسليح شبكتين .



يتم تصميم كل سطح على حده

١ – نحسب (T_{max}) و هى أكبر Compression Force على السطح سواء T_2 او T_1

٢ – نحسب $Actual\ Stress = \frac{T_{max}}{A_c} = \frac{T_{max}}{1000 * t_s}$

٣ – نحسب $Allowable\ Stress = \frac{F_{co}}{2}$

٤ – نقارن ال Actual Stress بال Allawable Stress

IF Actual working Stress $\leqslant$ Allowable working Stress $\longrightarrow$ (t_s) is o.k.

IF Actual working Stress $>$ Allowable working Stress $\longrightarrow$ increase (t_s)

٥ – لتحديد قيمه تسليح T_1 هناك حالتان :

أ- اذا كانت كل قيم T_1 على السطح كلها Compression

نستخدم أقل تسليح $5\phi 8 \backslash m'$ For st. 240/350

$5\phi 10 \backslash m'$ For st. 360/520

ب- اذا وجدت قيم ل T_1 على السطح Tension نصمم حديد T_1 على اكبر قيمه لل Tension

$T_{1\,(U.L.)} = 1.5 * T_1$

$$\boxed{A_{s\,(T_1)} = \frac{T_{1\,(U.L.)}}{F_y \backslash \delta_s}}$$

٦ – لتحديد قيمه تسليح T_2 هناك حالتان :

أ- اذا كانت كل قيم T_2 على السطح كلها Compression

نستخدم أقل تسليح $5\phi 8 \backslash m'$ For st. 240/350

$5\phi 10 \backslash m'$ For st. 360/520

ب- اذا وجدت قيم ل T_2 على السطح Tension نصمم حديد T_2 على اكبر قيمه لل Tension

$T_{2\,(U.L.)} = 1.5 * T_2$

$$\boxed{A_{s\,(T_2)} = \frac{T_{2\,(U.L.)}}{F_y \backslash \delta_s}}$$

Special Case. (Water Sections)

فى حاله الاسطح المعرضه مباشره للماء (Water Sections)
يجب مراعاه الاتى :

١ – أن تكون $\boxed{t_{s\,min} = 160\ mm}$

٢ – يتم استخدام شبكتين حديد علويه و سفليه .

– اذا كانت قيم T_1 او T_2 كلها Compression نأخذ التسليح شبكتين لكن minimum

– اذا كانت قيم T_1 او T_2 بها Tension نحدد قيمه اكبر Tension Force
مره فى اتجاه T_1 و مره أخرى فى اتجاه T_2

$$A_{s\,Total} = \frac{1.5 * T_{max}}{F_y / \gamma_s}$$ ------ فى كل اتجاه على حده

$$A_s \backslash Side = \frac{A_{s\,Total}}{2}$$

$\not< 5 \phi 8$ For st. 240/350

$\not< 5 \phi 10$ For st. 360/520

٣ – يتم عمل Check بمقارنه قيمه اكبر اجهاد شد موجود فى القطاع
بقيمه أكبر اجهاد شد تتحمله الخرسانه حتى لا يحدث شروخ فى القطاع
فتنفذ المياه الى الحديد مسببه له الصدأ .

نحسب (T_{max}) و هى أكبر Tension Force على السطح سواء T_2 او T_1

$$\text{Actual Tension Stress} = \frac{T_{max}}{A_c} = \frac{T_{max}}{1000 * t_s} \quad (N/mm^2)$$

$$\text{Allowable Tension Stress} = \frac{F_{ctr}}{\eta} = \frac{0.6\sqrt{F_{cu}}}{1.7}$$

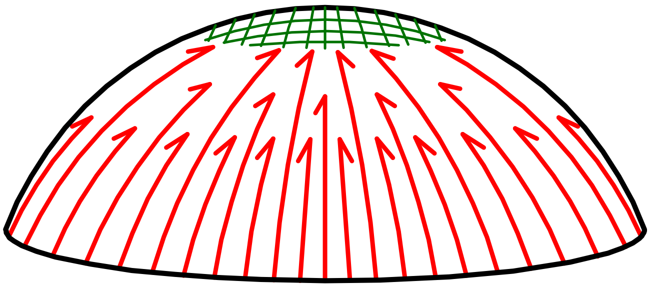
حيث η هى معامل امان يتوقف على تخانه البلاطه و سيتم تحديدها بالتفصيل عند دراسه التتكات .

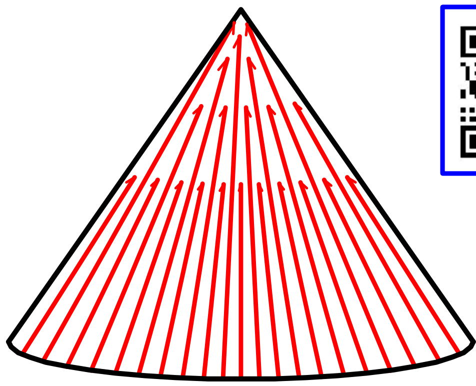
IF Actual Stress $\leqslant$ Allowable Stress $\longrightarrow$ (t_s) is o.k.

IF Actual Stress $>$ Allowable Stress $\longrightarrow$ increase (t_s)

Reinforcement of S.O.R.

Reinforcement of Meridian Direction (T_1)



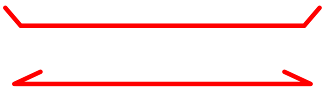


Elevation
Plan

جنش لاسفل

① التسليح العلوى (T_1)

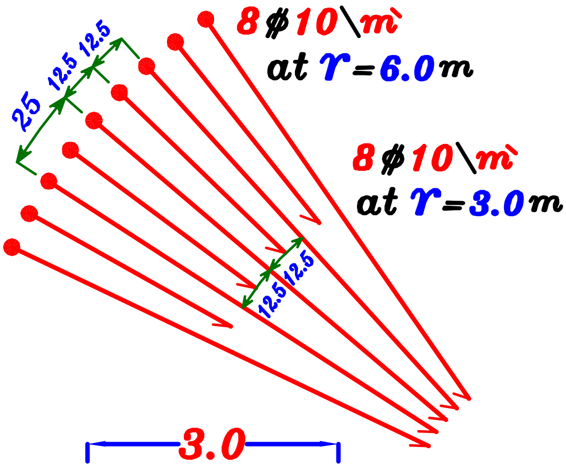
Elevation
Plan



جنش لاعلى

② التسليح السفلى (T_1)

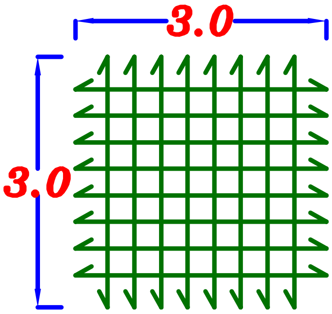
ممكن رسم الجنش فى اى اتجاه مادام تم تحديد ما اذا كان حديد سفلى ام علوى



③ تسليح (T_1) فى ال Plan

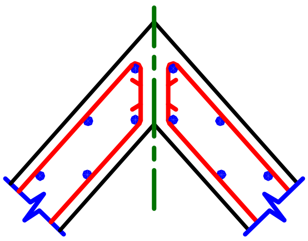
مثال 8 ϕ10\m` أى أن المسافه

بين كل سيخين متتاليين = ١٢,٥٠ سم

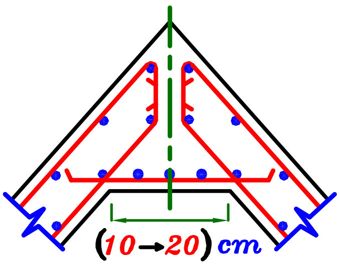


④ توجد شبكه 5 ϕ10\m` فى وسط ال Dome

عاده تؤخذ ابعادها (3.0 m × 3.0 m)



NO mesh

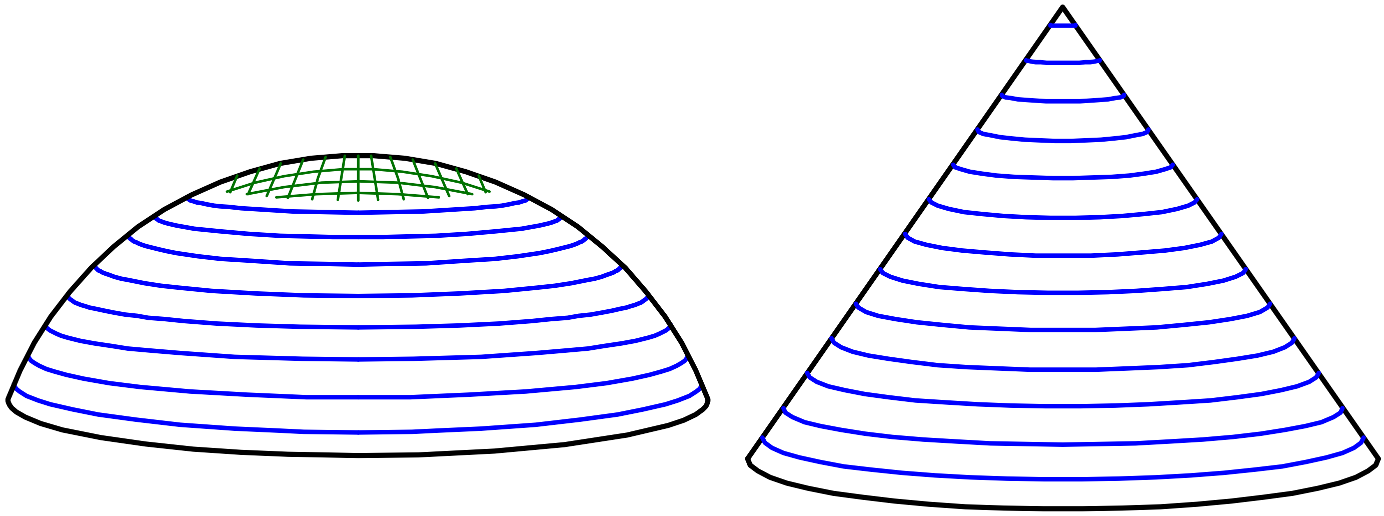


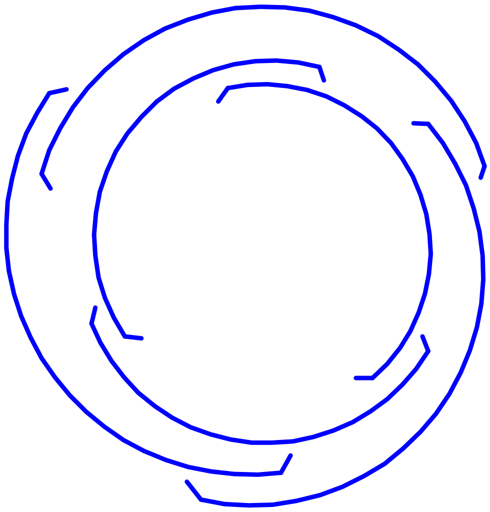
mesh 5 ϕ10\m`

لا يتم رسم هذه الشبكه فى ال Cone

لانها اما صغيره جدا او غير موجوده

Reinforcement of Ring Direction (T_2)



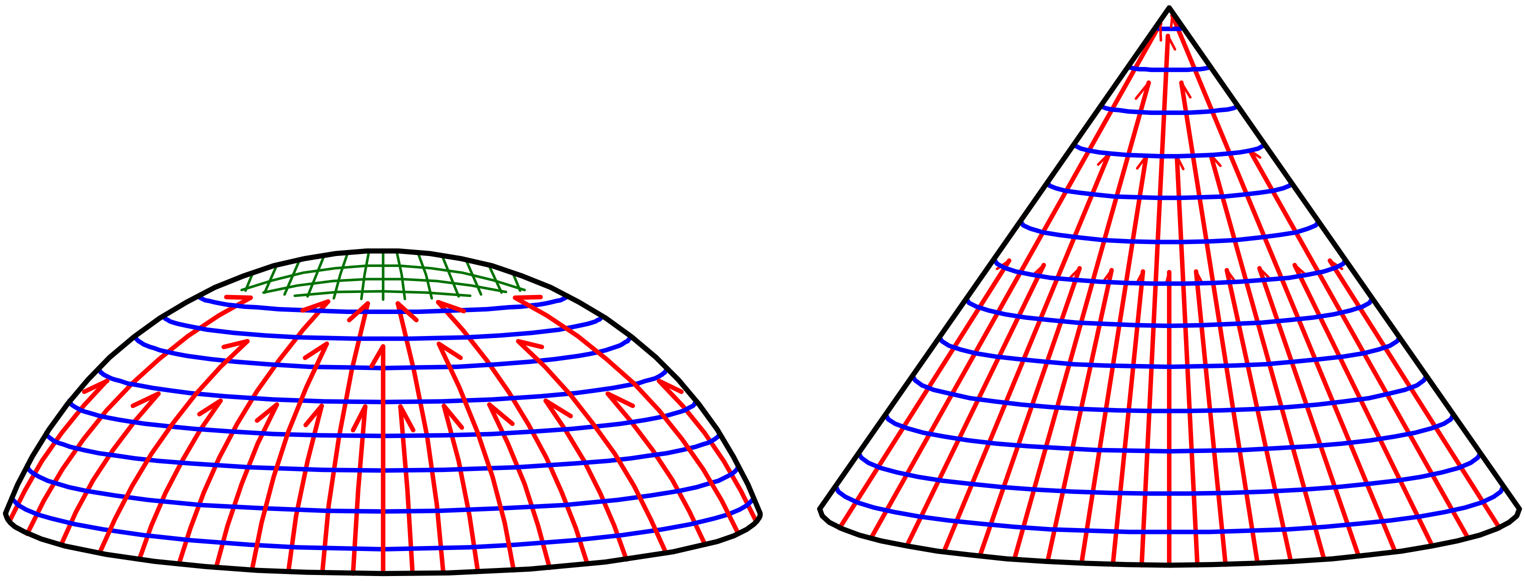


تسليح (T_2) يكون دائرى

و عند عمل وصلات فيه يجب ان تكون بالتبادل

staggered splices

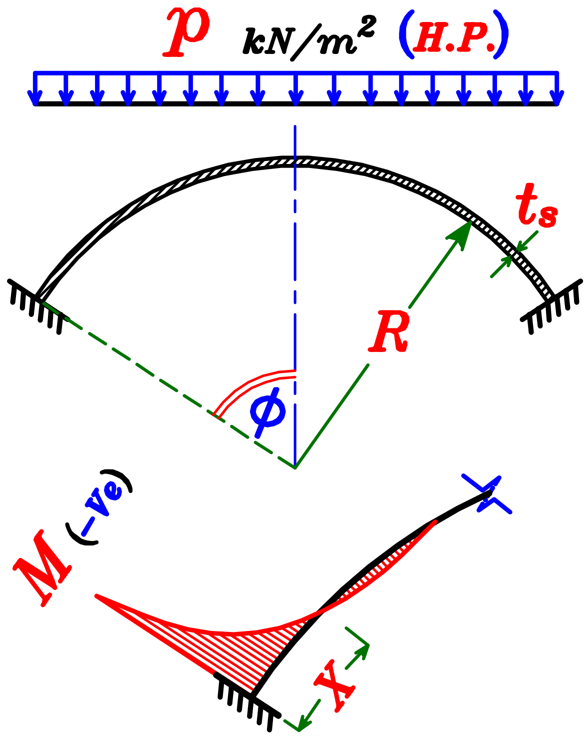
Plan



Reinforcement of (T_1) & (T_2)

$(-Ve)$ Bending Moment at edges.

يتم حساب قيمه العزم السالب
الناتج عن اتصال البلاطه بالكمره
من المعادله التاليه :



$$\boxed{M_{(-Ve)} = \frac{p * R * t_s}{3}}$$ فى اتجاه T_1

Use Additional $(-Ve)$ Steel. For T_1

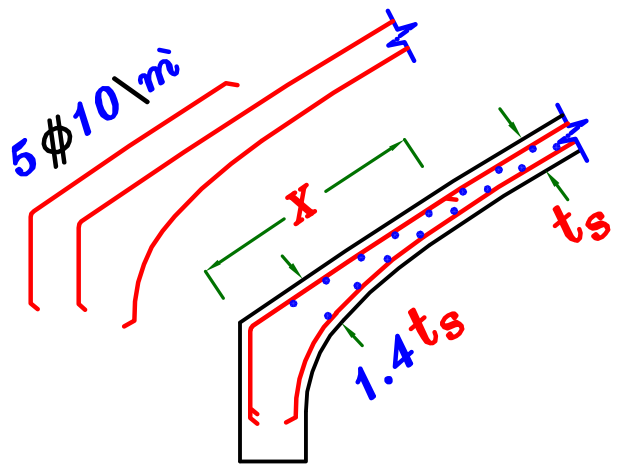
$A_{s\,(-Ve)\,(add.)} = 5\phi 8 \backslash m'$ For st. 240/350

$5\phi 10 \backslash m'$ For st. 360/520

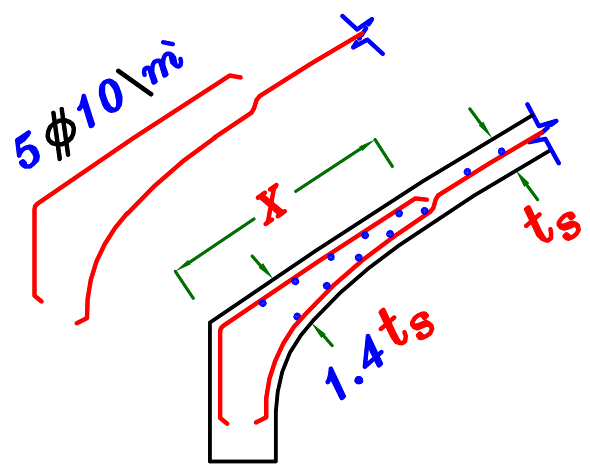
where $\boxed{X = 0.6\sqrt{R * t_s}} \not< 1.0\,m$ يمتد لمسافه (X)

$\boxed{t = 1.4\,t_s}$ يتم زياده تخانه البلاطه فى هذه المنطقه

و ذلك لمقاومه الـ Shear و الـ moment $(-Ve)$ الناتجه عن اتصال البلاطه بالكمره .



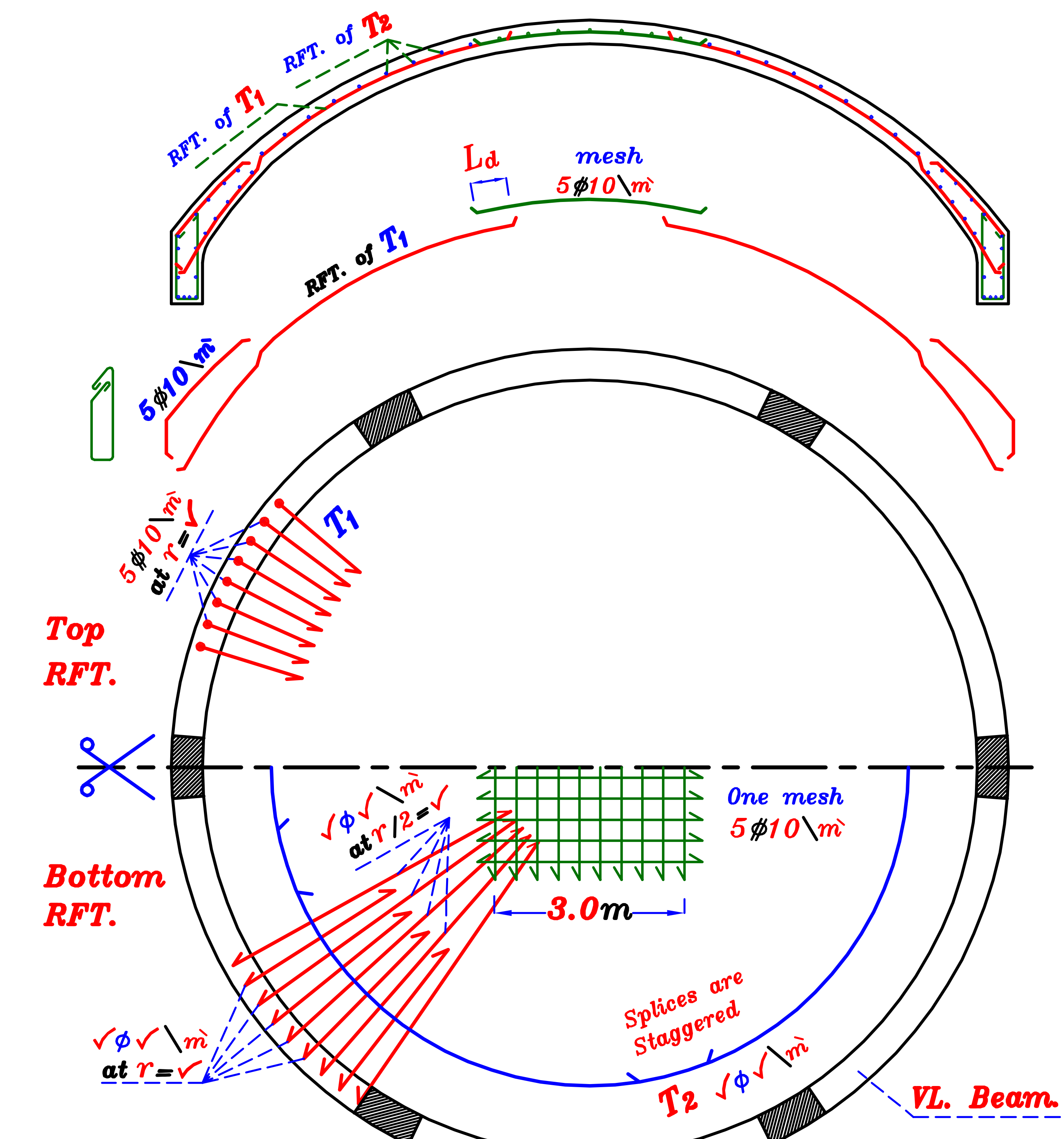
For double mesh



For Single mesh

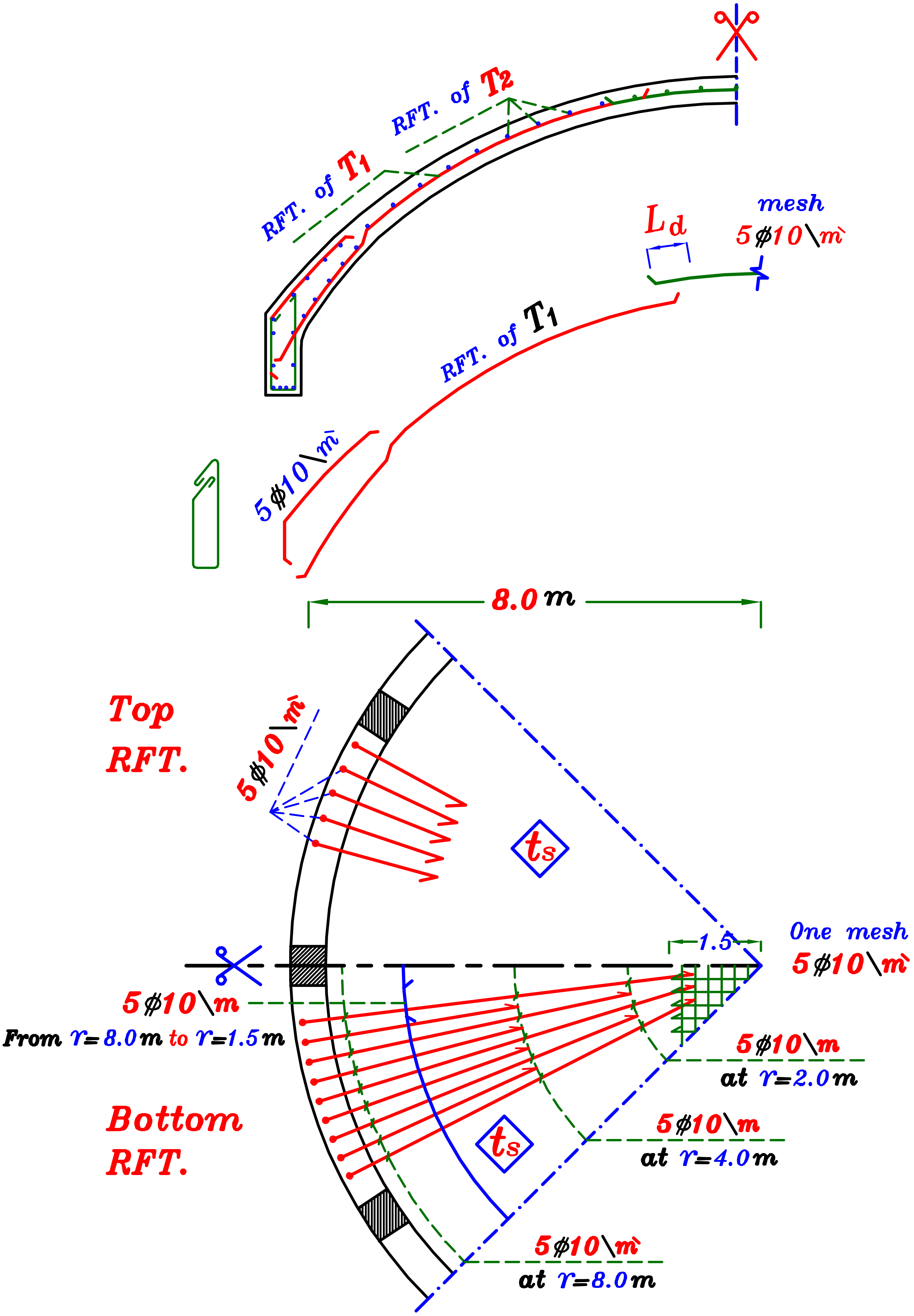
Reinforcement in Plan.

Dome with Single layer mesh.



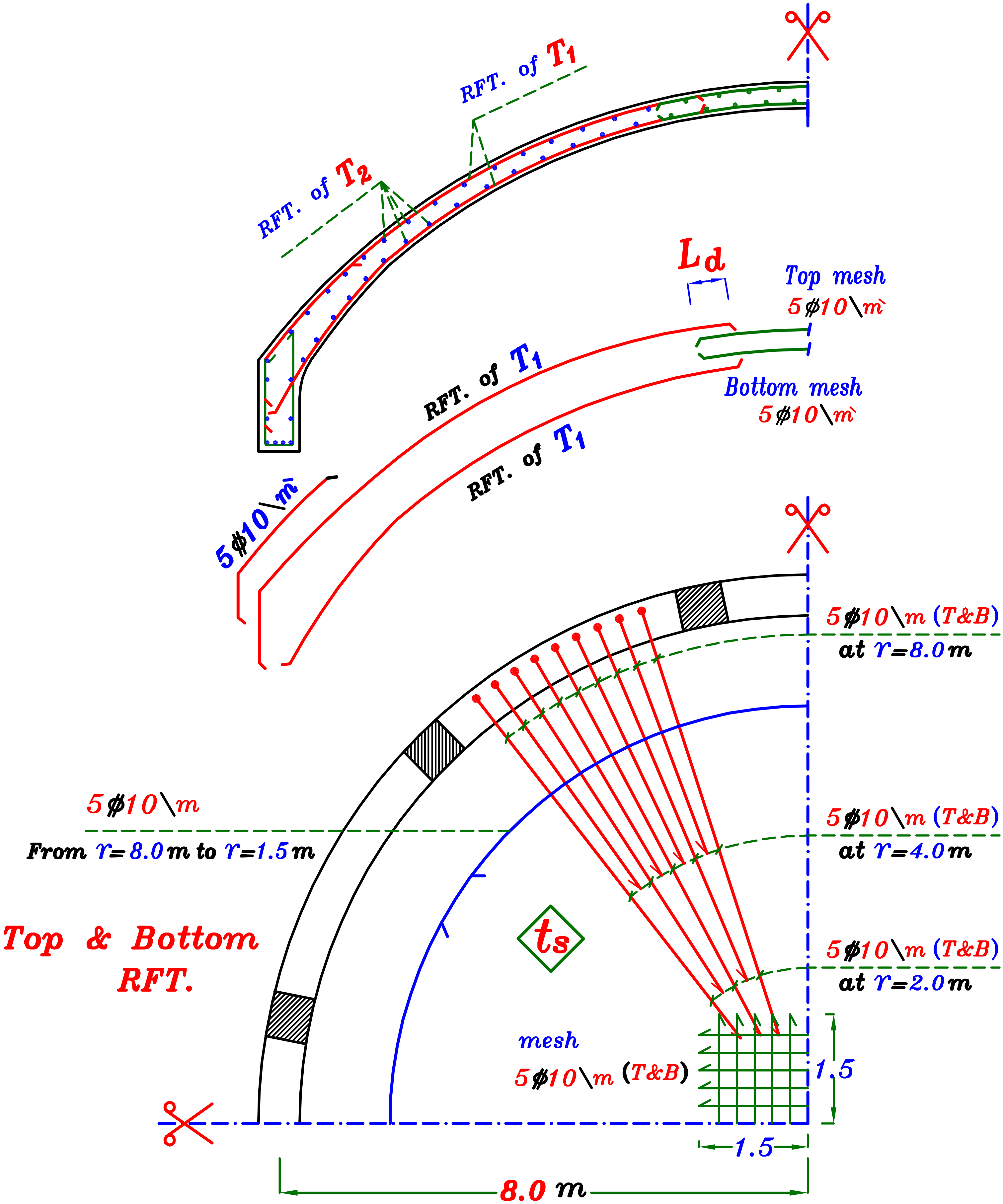
حديد (T_1) يظهر فى ال plan فى صوره خطوط متجهه الى مركز الدائره و يتم توقيف نصف كميه الحديد (بالتبادل) عند نصف المسافه الى المركز ثم توقيف نصف الكميه المكمله عند نصف المسافه المتبقيه و هكذا أى عند (...... $\frac{R}{8}$, $\frac{R}{4}$, $\frac{R}{2}$) و ذلك لان المسافه تقل تدريجيا الى مركز الدائره و يمتد حديد (T_1) حتى نصل الى الشبكه فى حاله ال Dome اما حديد (T_2) يظهر فى ال plan على شكل دوائر تبدأ من طرف السطح و تنتهى عند الشبكه فى ال Dome

عاده نرسم $(\frac{1}{4}\ plan)$ و نبين الحديد السفلى على $(\frac{1}{8}\ plan)$ و الحديد العلوى على $(\frac{1}{8}\ plan)$
و الشبكه تستمر لمسافه $(1.5\,m)$ فى الاتجاهين .
نضع حديد (T_2) و يظهر فى ال **plan** على شكل دائره تبدأ من طرف السطح الى ان تصل الى الشبكه .

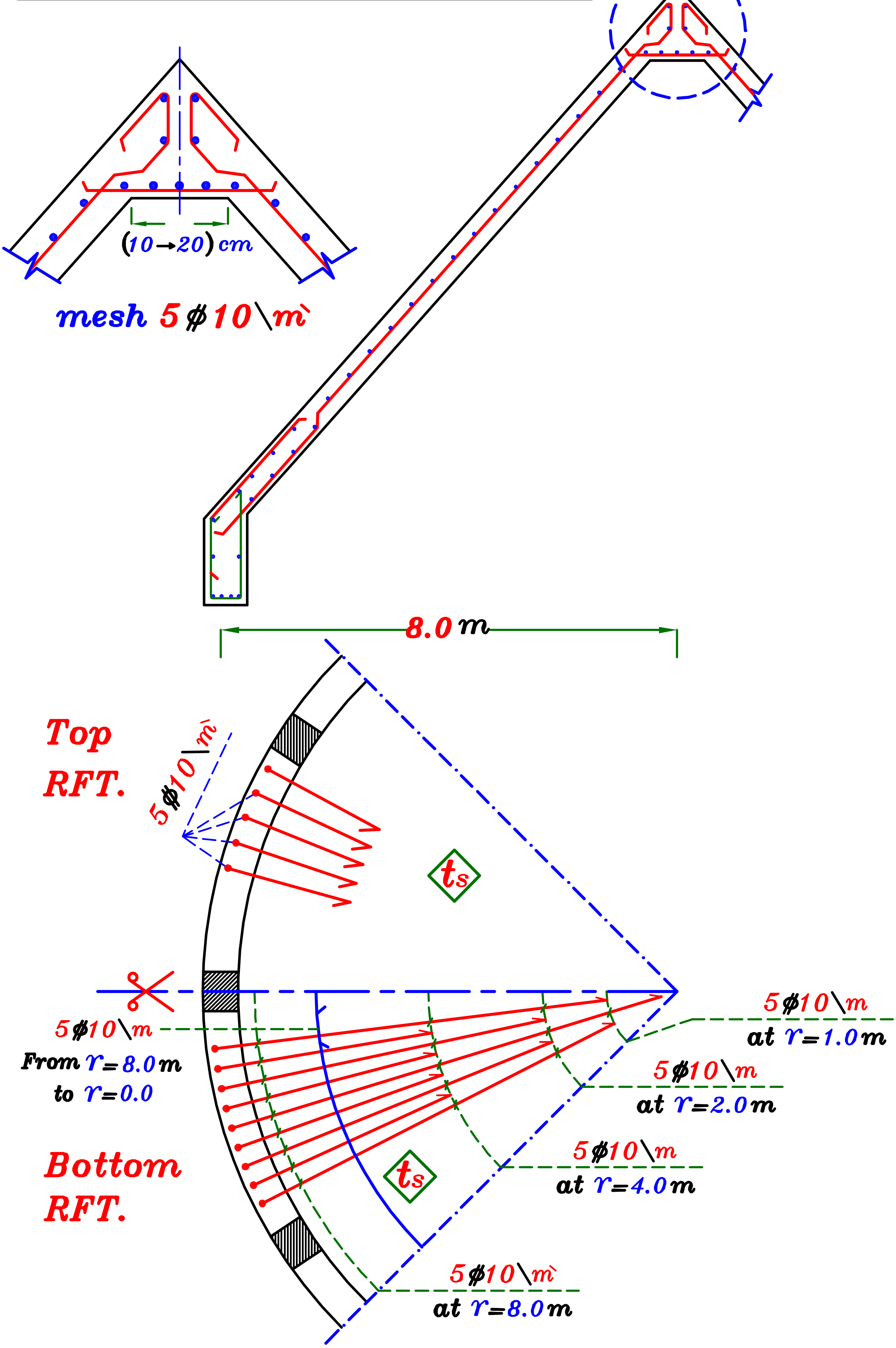


Dome with Double layer mesh.

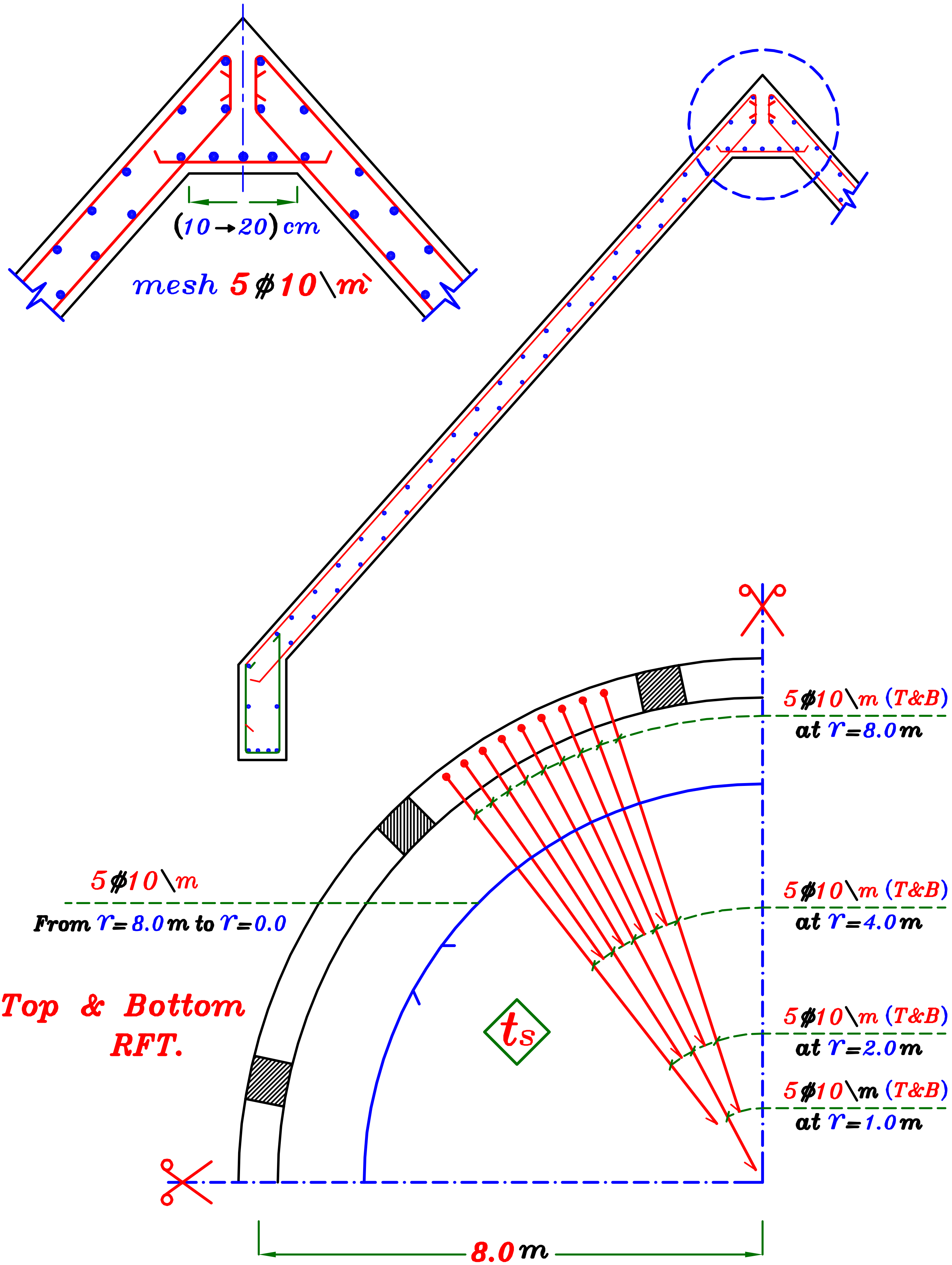
نرسم $(\frac{1}{4}$ plan$)$ و نبين عليه الحديد السفلى و العلوى مره واحده (Top & Bottom)



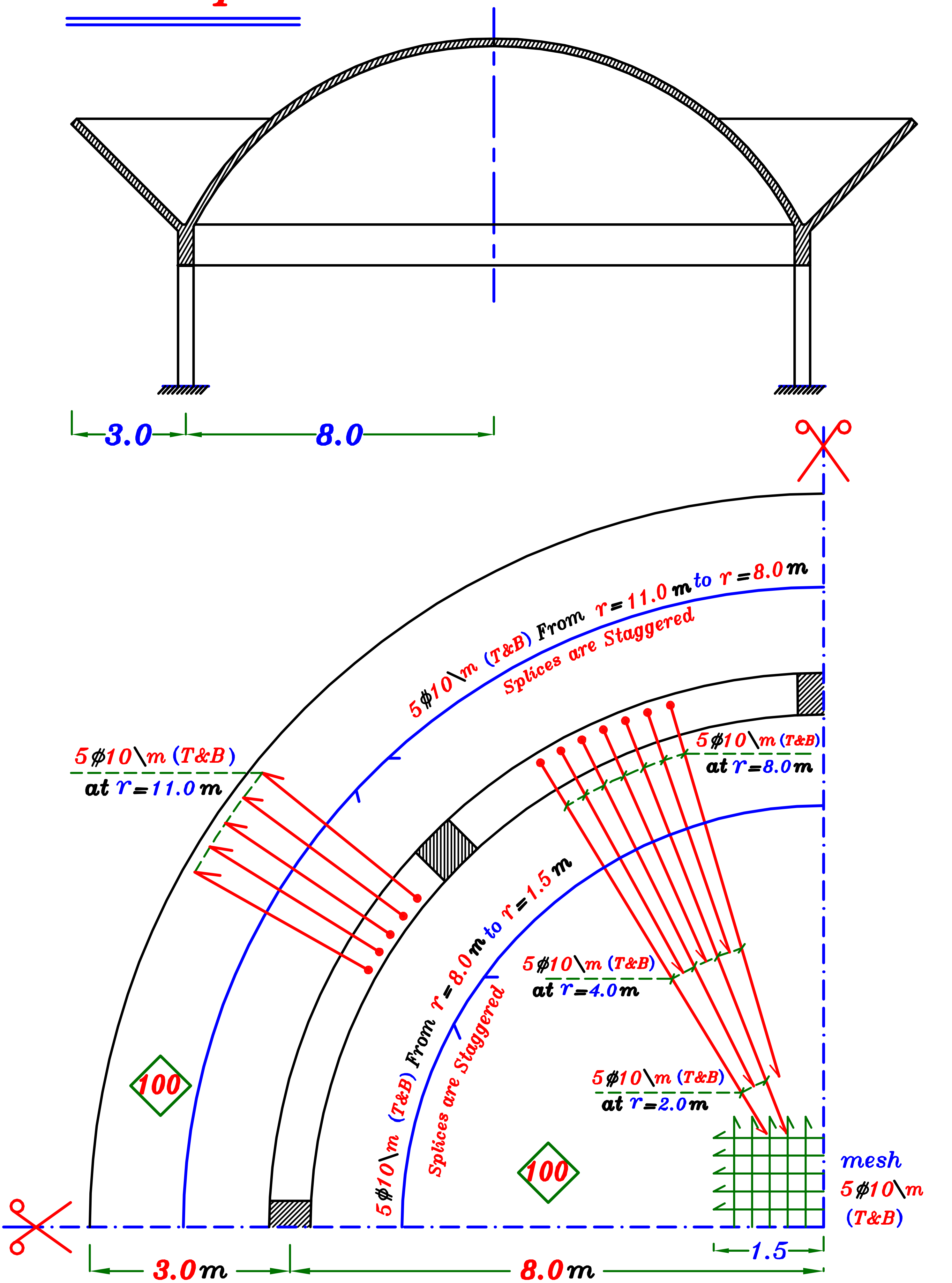
Cone with Single layer mesh.



Cone with Double layer mesh.

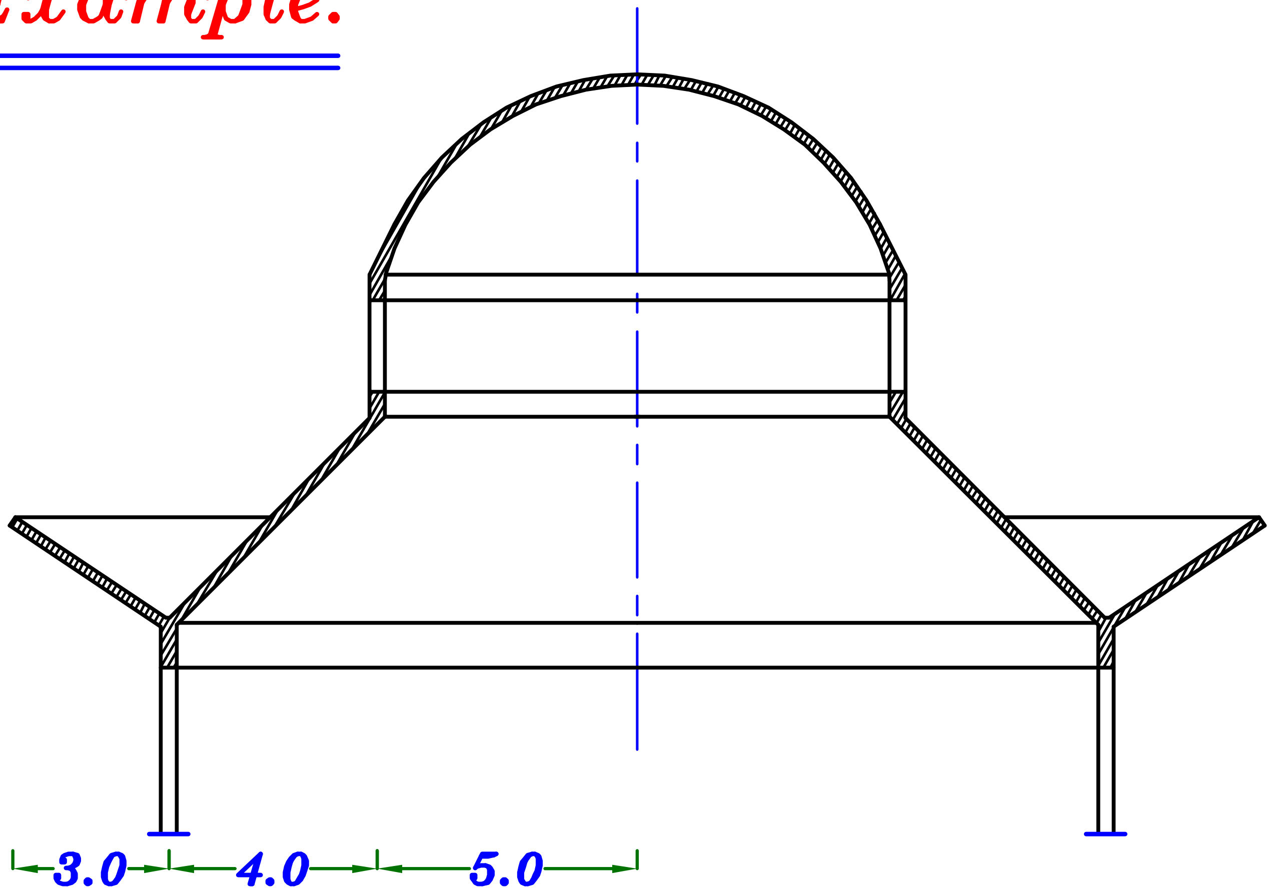


Example.

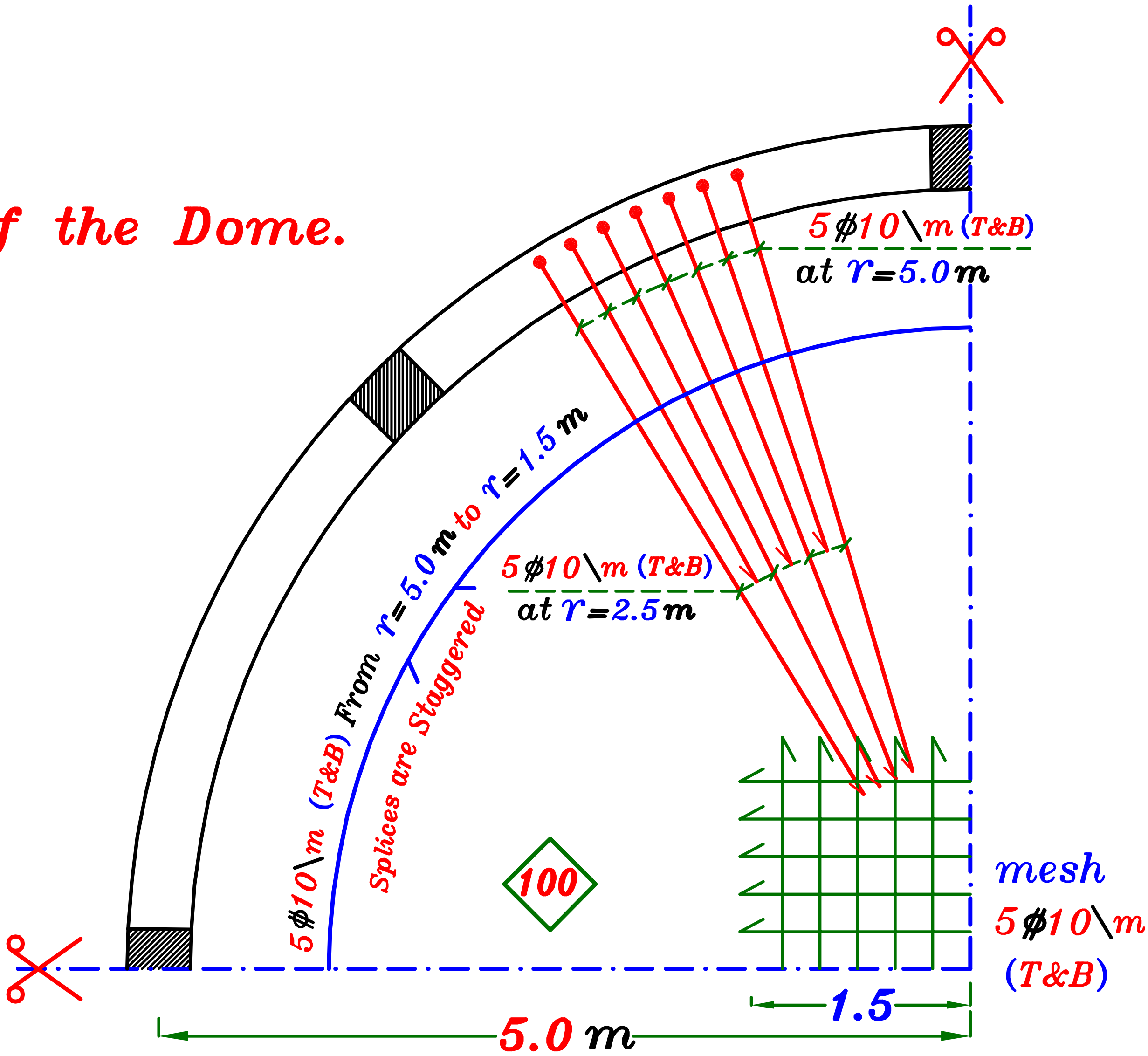


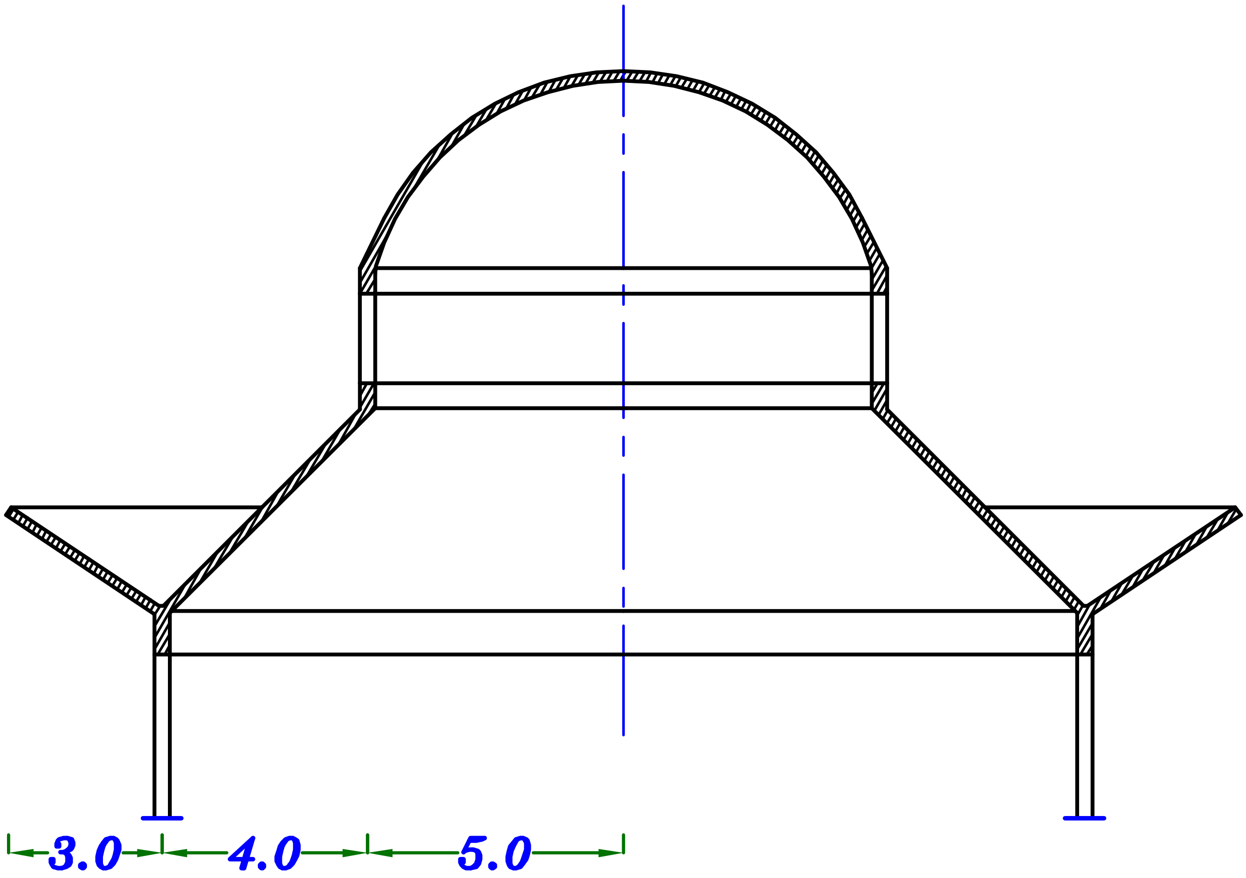
3.0
8.0
5φ10\m (T&B) From r = 11.0 m to r = 8.0 m
Splices are Staggered
5φ10\m (T&B)
at r = 11.0 m
5φ10\m (T&B)
at r = 8.0 m
5φ10\m (T&B) From r = 8.0 m to r = 1.5 m
Splices are Staggered
5φ10\m (T&B)
at r = 4.0 m
5φ10\m (T&B)
at r = 2.0 m
100
100
mesh
5φ10\m
(T&B)
1.5
3.0 m
8.0 m

Example.

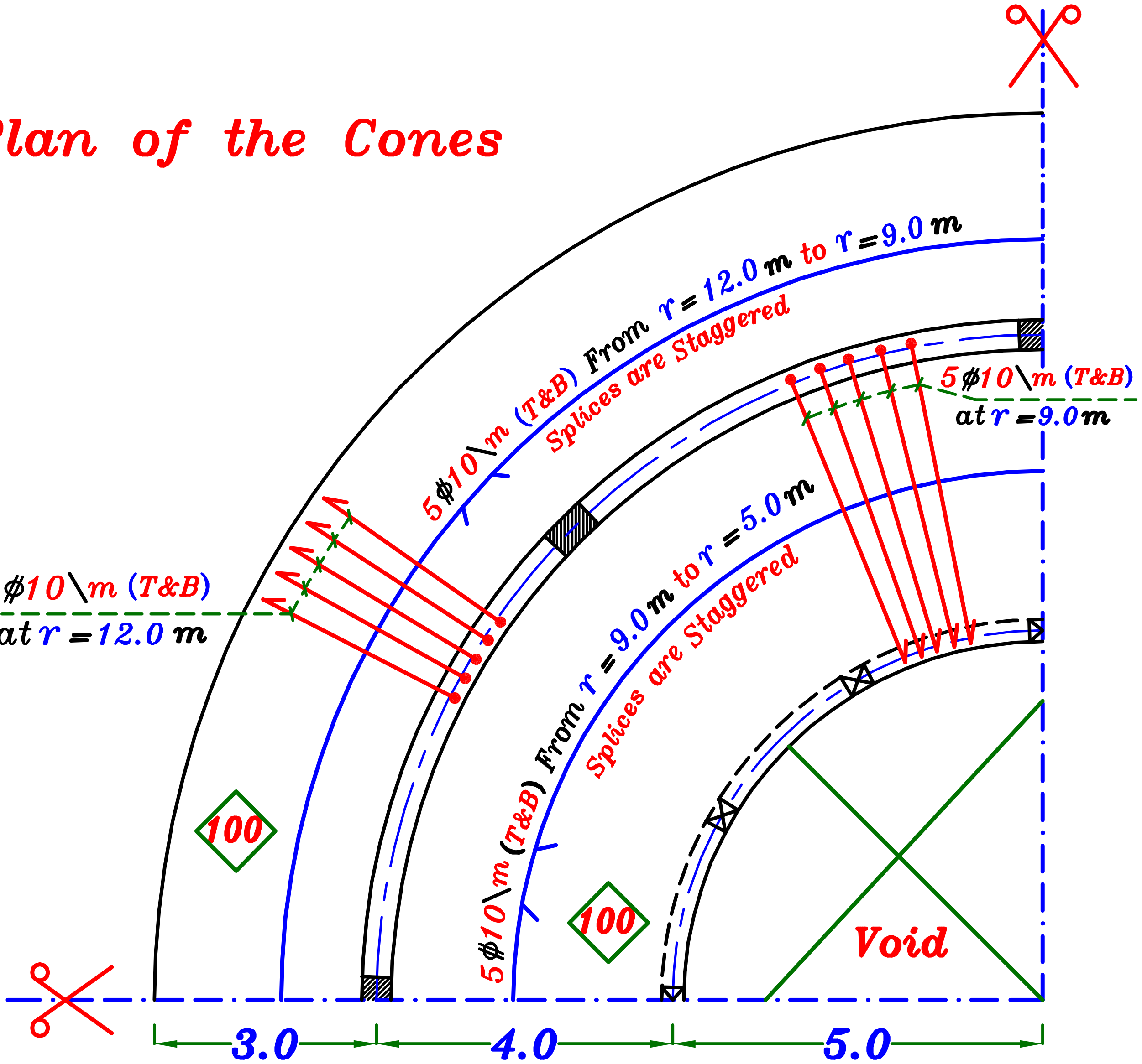


Plan of the Dome.

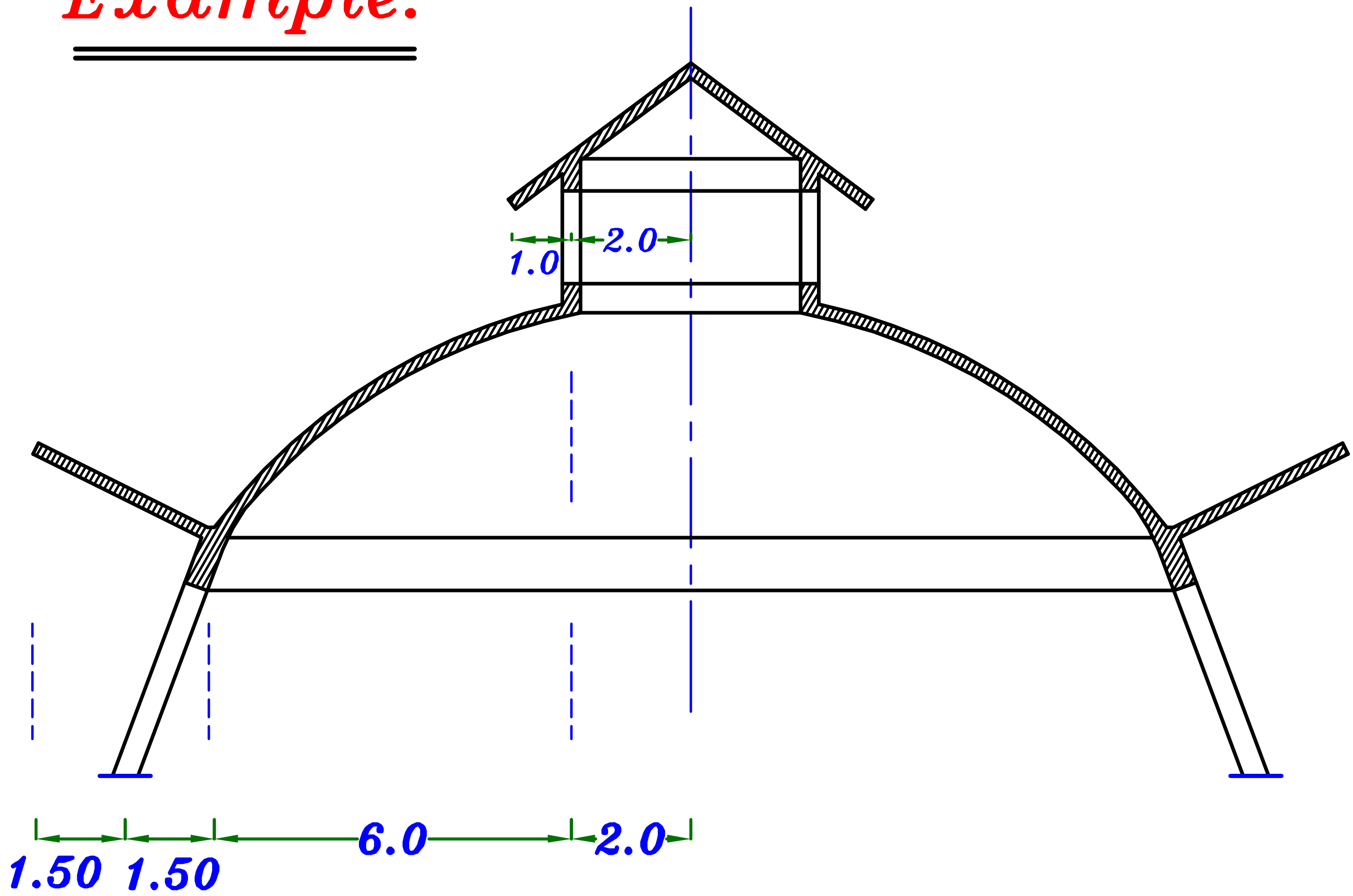




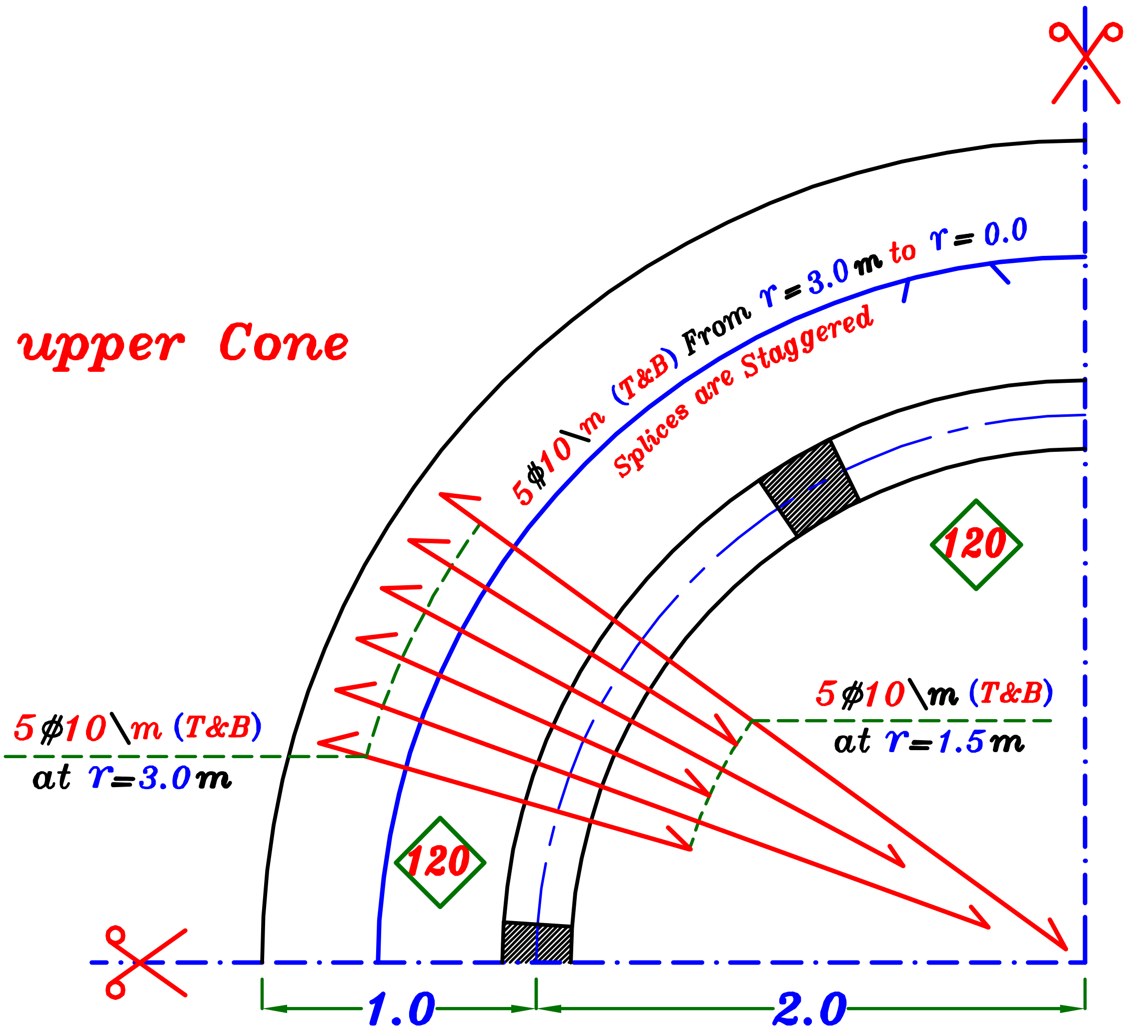
Plan of the Cones

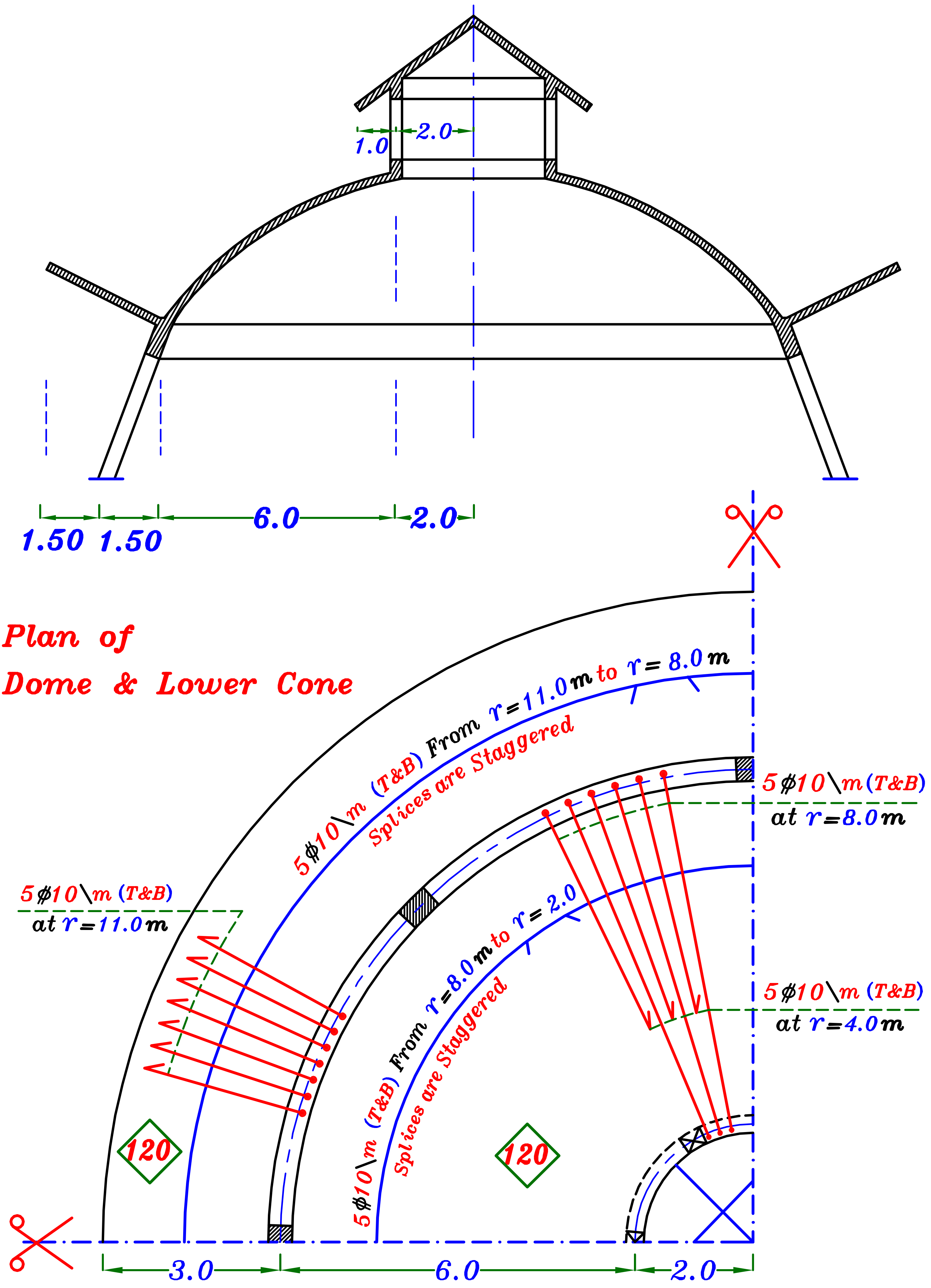


Example.



Plan of upper Cone





1.0
2.0
1.50
1.50
6.0
2.0
Plan of
Dome & Lower Cone
5ϕ10\m (T&B) From r=11.0 m to r= 8.0 m
Splices are Staggered
5ϕ10\m (T&B)
at r=11.0 m
5ϕ10\m (T&B)
at r=8.0 m
5ϕ10\m (T&B) From r=8.0 m to r= 2.0
Splices are Staggered
5ϕ10\m (T&B)
at r=4.0 m
120
120
3.0
6.0
2.0

Calculating Straining Actions For Ring Beams.

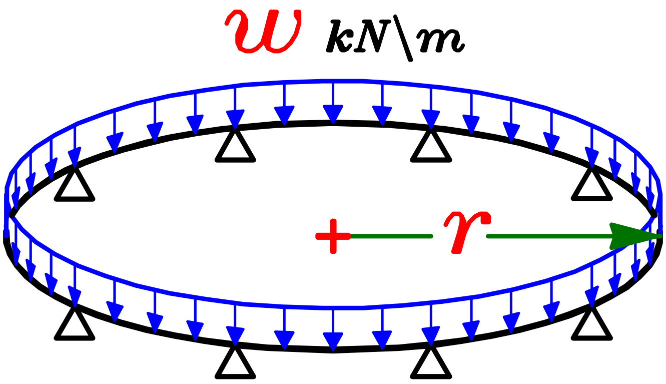
P = Total load on the beam. (kN)

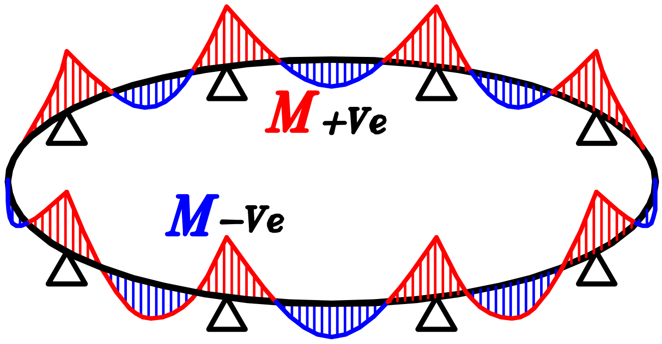
w = Load per meter. (kN/m`)

r = Radius of the beam. (m)

n = Number of supports.

$$\boxed{P = w * 2\pi r}$$





لحساب ال Bending Moment & Shear Force & Torsional Moment المؤثرين على الكمره ممكن استخدام الجدول التالى

Old Tables Page 120

No. of supports	Load on each support	Max. Shearing Force	Max. Bending Moment at C.L. of Span	Max. Bending Moment Over C.L. of Column	Max. Torsional Moment	Central angle
n	R	$Q_{max.}$	M_{+Ve}	M_{-Ve}	$M_{t\,max.}$	θ
4	P/4	P/8	0.0176 Pr	− 0.0322 Pr	0.0053 Pr	19° 21`
6	P/6	P/12	0.0075 Pr	− 0.0148 Pr	0.0015 Pr	12° 44`
8	P/8	P/16	0.0042 Pr	− 0.0083 Pr	0.0006 Pr	9° 33`
10	P/10	P/20	0.0032 Pr	− 0.0052 Pr	0.0004 Pr	7° 36`
12	P/12	P/24	0.0019 Pr	− 0.0037 Pr	0.0002 Pr	6° 21`

ال (θ) Central angle هى الزاويه المقاسه من ال Support حتى النقطه التى يوجد عندها max. Torsional moment

Data for Design of Reinforced Concrete Structures

1. Circular Beams

Supported on a number of supports (n) at equal distance under uniformaly dist.^{ed} load (pt/m')

$$M = pr^2\left[\pi/n \ \frac{\cos\phi}{\sin\phi_0} - 1\right]$$

$$M_t = -pr^2\left[\pi/n \ \frac{\sin\phi}{\sin\phi_0} - \phi\right]$$

$$Q = -p.r.\phi$$

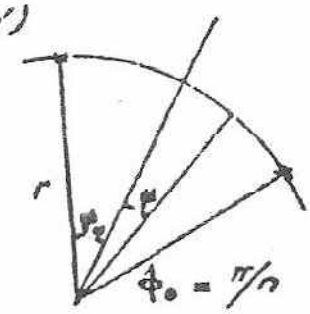


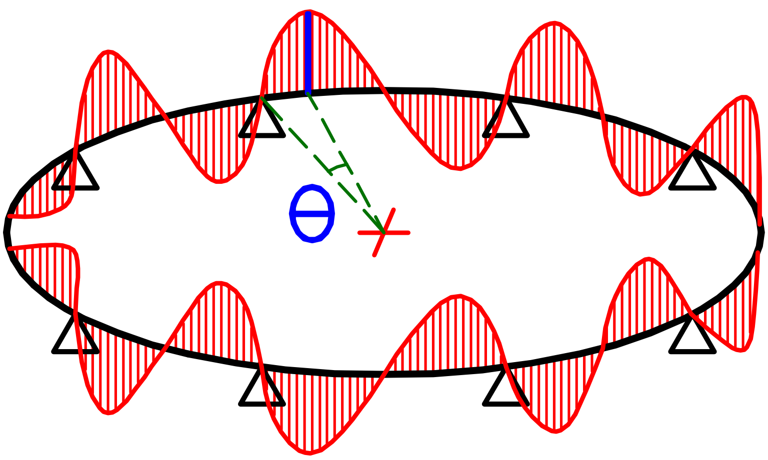
Table of extreme values

$P = 2\pi r p$

Number of Supports (n)	Load on each column R	Max. Shearing force $Q_{max.}$	Max. Bending M: At center of span M (+)	Max. Bending M: Over Support M (-ve)	Max. Torsional moment M_t	Central angle between Axis of Support & Sec. of max. (M_t)
4	P/4	P/8	.0176 Pr	-.0322 Pr	.0053 Pr	19° 21'
6	P/6	P/12	.0075 Pr	-.0148 Pr	.0015 Pr	12° 44'
8	P/8	P/16	.0042 Pr	-.0083 Pr	.0006 Pr	9° 33'
10	P/10	P/20	.0032 Pr	-.0052 Pr	.0004 Pr	7° 36'
12	P/12	P/24	.0019 Pr	-.0037 Pr	.0002 Pr	6° 21'

$M_{t\ max.}$

Central angle (θ)



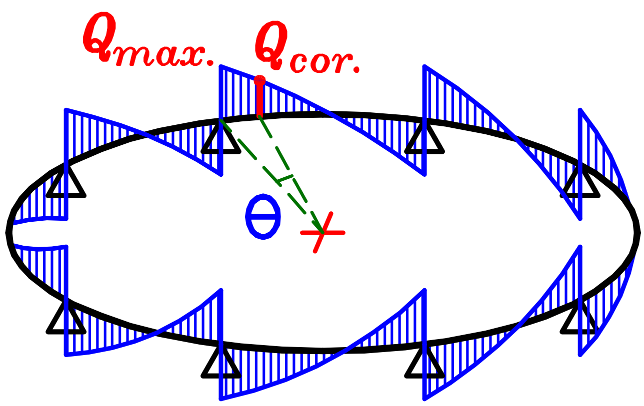
T.M.D.

ملاحظات هامه .

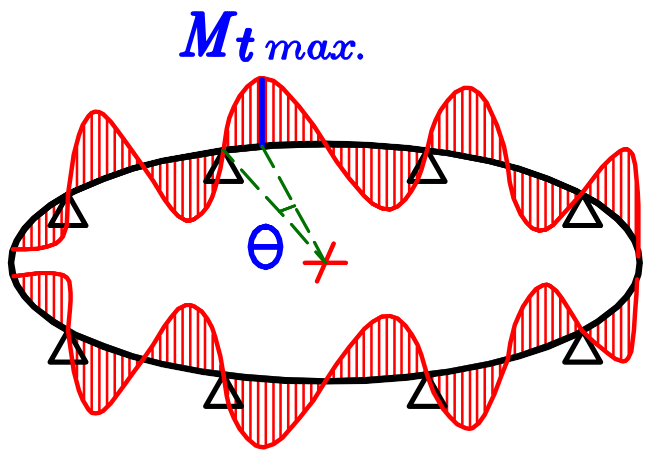
١- ال (θ) *Central angle* هى الزاويه المقاسه من ال *Support* حتى النقطه التى يوجد عندها *max. Torsional moment*

أى أن ال *Section* الذى يوجد عنده *max. Torsional moment* مكانه غير ال *Section* الذى يوجد عنده *max. Shear Force*

لذا عند تصميم الكانات لنتحمل *Shear + Torsion* نحدد قيمه $Q_{corresponding}$ و هى قيمه ال *Shear Force* عند ال *Section* الذى يوجد عنده *max. Torsion*



S.F.D.



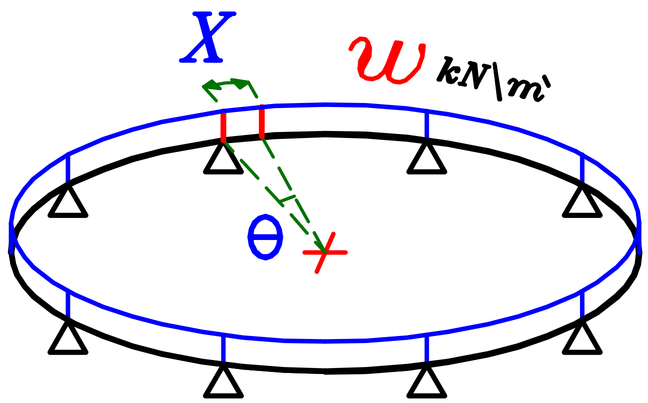
T.M.D.

Radian

$$X = r * \theta = r * \theta * \frac{\pi}{180}$$

$$\boxed{X = r * \theta * \frac{\pi}{180}}$$

$$\boxed{Q_{cor.} = Q_{max} - w * X}$$



ممكن للتسهيل تصميم القطاع على $(M_{t\,max.} \,,\, Q_{max})$

٢- اذا كان عدد ال **Supports** اكبر من او يساوى ١٢ $(n \geqslant 12)$ فمن الممكن :

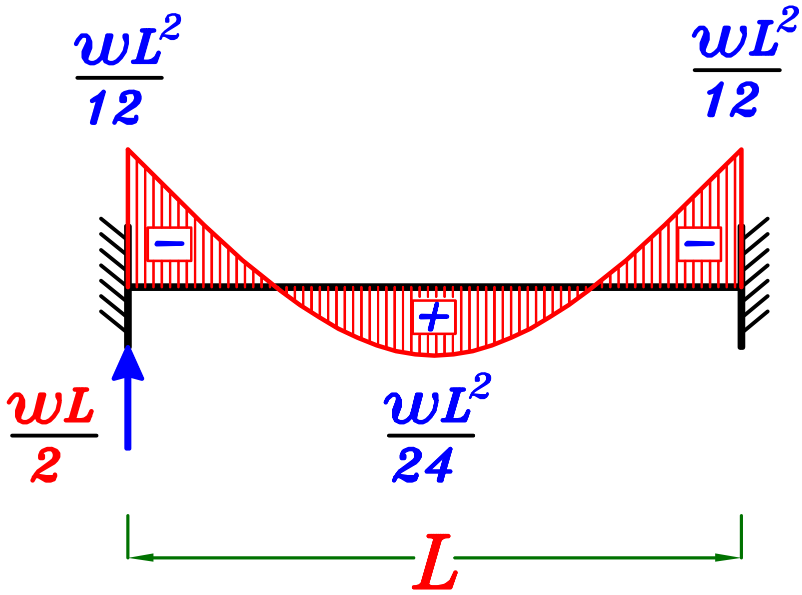
أ- نهمل عزم الالتواء (M_t) لان قيمته ستكون صغيره جدا .

ب- ممكن حساب ال **max. Shear Force** & **max. Bending Moment** كالاتى :

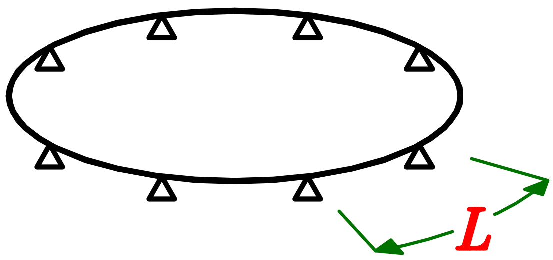
$$\boxed{max.\ M_{-Ve} = \frac{wL^2}{12}}$$

$$\boxed{max.\ M_{+Ve} = \frac{wL^2}{24}}$$

$$\boxed{Q_{max.} = \frac{wL}{2}}$$



where $\boxed{L = \frac{2\pi r}{n}}$



يصمم قطاعان فى الكمره على أكبر M_{+ve} و أكبر M_{-ve}

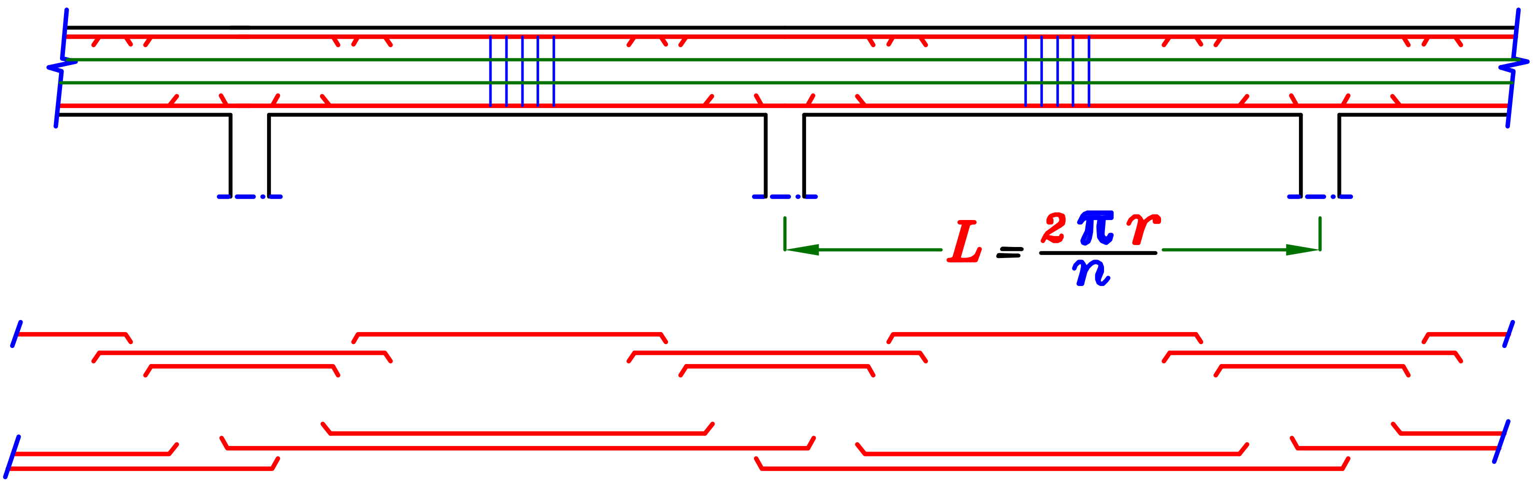
و يتم تصميم الكانات و ال **Longitudinal bars** على M_t , $Q_{cor.}$

و تكون القيمه النهائيه للتسليح

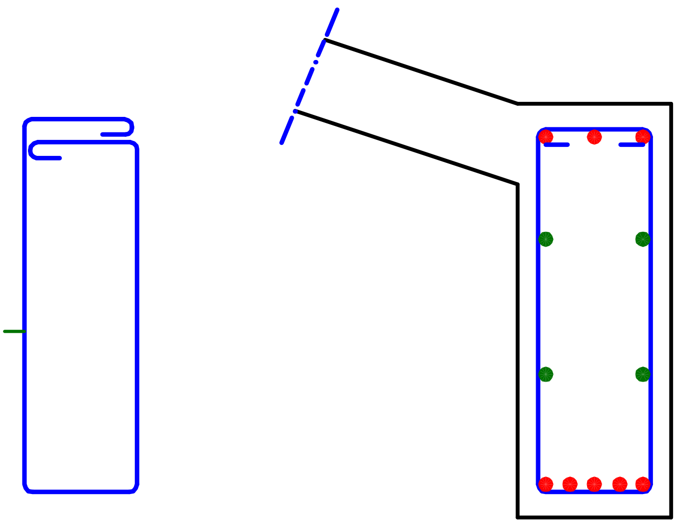
$$\boxed{A_{s\,total} = A_s + \frac{A_{sl}}{4}}$$

و يرسم تسليح الكمره بعد فردها

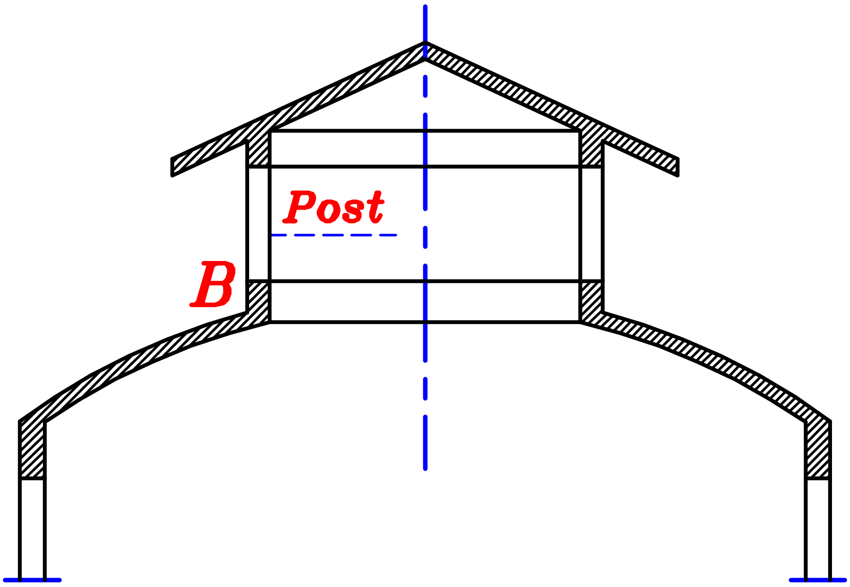
Developed Elevation of Beams.



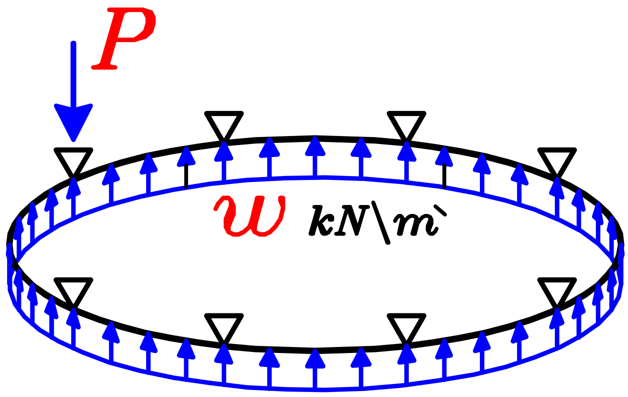
Closed Stirrups



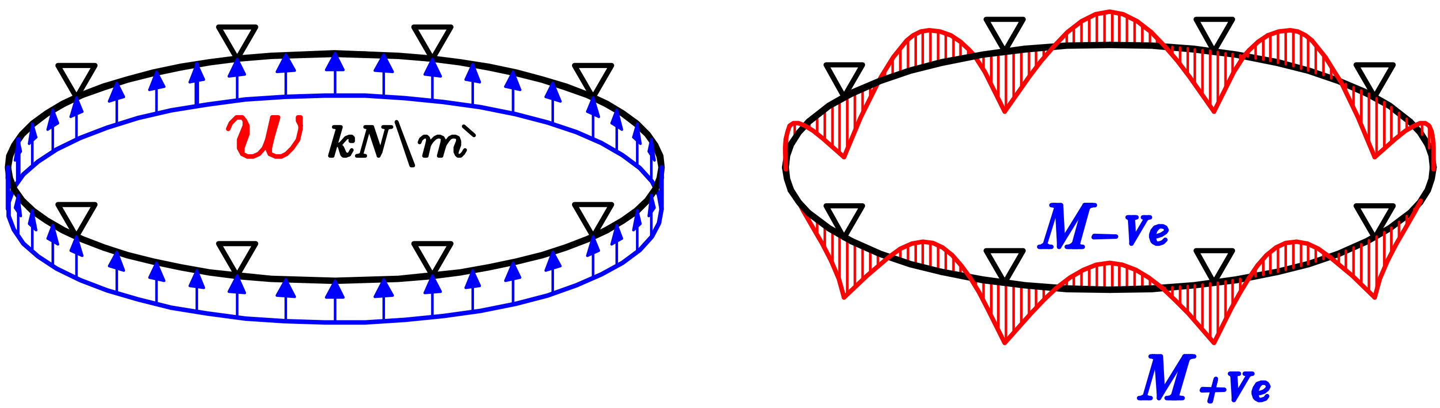
٣- اذا كانت محصله القوى الرأسيه المؤثره على الكمره الدائريه تؤثر الى اعلى .
مثل الكمره B



$$w = \frac{\sum P}{2 \pi r}$$



سيظل ***max. Shear Force & max. Torsional Moment*** كما هم .
لكن اتجاه و قيمه كلا من ($max. M_{-Ve}$) و ($max. M_{+Ve}$) سينعكس اتجاهه
و ستكون قيمته فى الجدول من هى قيمه العزم الاخر .



Example.

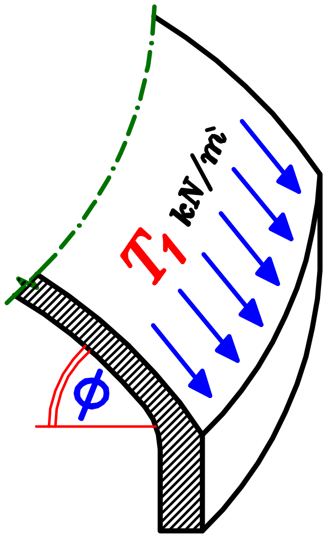
For $n = 8 \xrightarrow{\text{From Table}}$ $max. M_{-Ve} = -0.0042\ Pr$

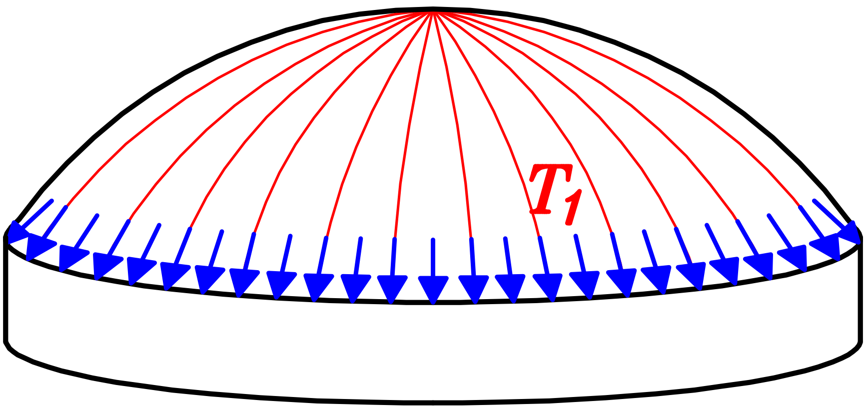
$max. M_{+Ve} = 0.0083\ Pr$

Calculating Loads on Ring Beams.

القوى المنقوله من السطح الدورانى الى الكمرات هى (T_1) ***Meridian Force*** فقط.

و ذلك لان (T_2) ***Ring Force*** متزنه داخلياً .

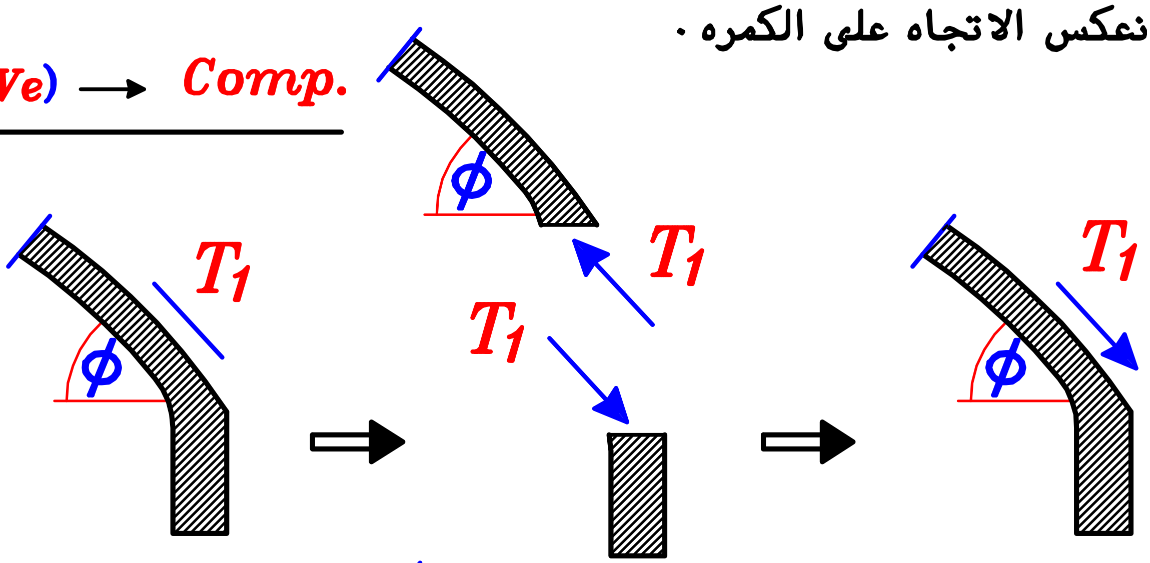




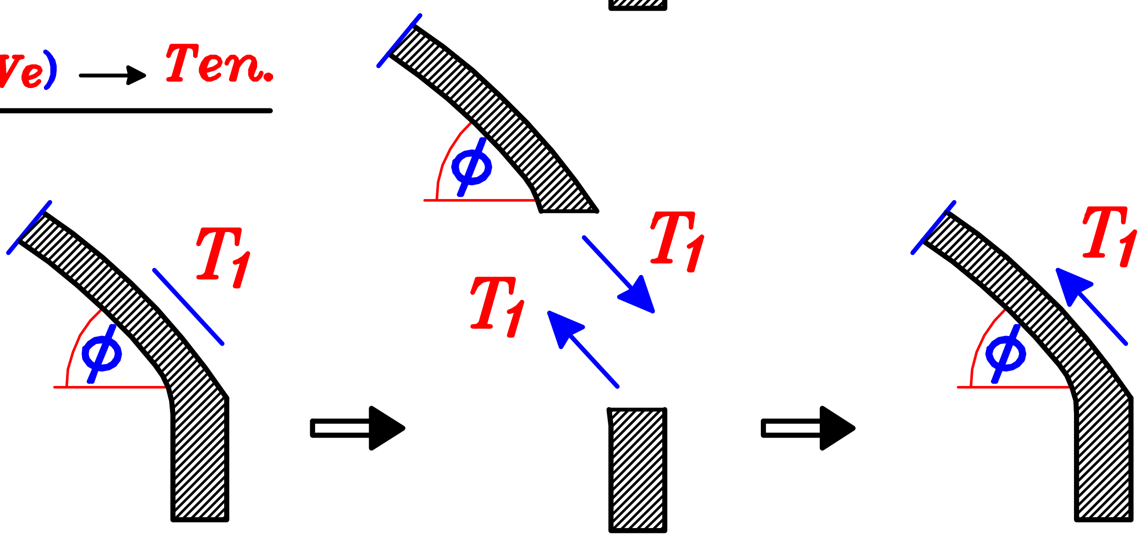
لتحديد اتجاه (T_1) اذا كانت فى اتجاه يضغط على الكمره ام اتجاه يشد الكمره .

نحدد من اشاره (T_1) اذا كانت $(+Ve)$ أم $(-Ve)$ و نحدد اتجاهها على السطح و منه نعكس الاتجاه على الكمره .

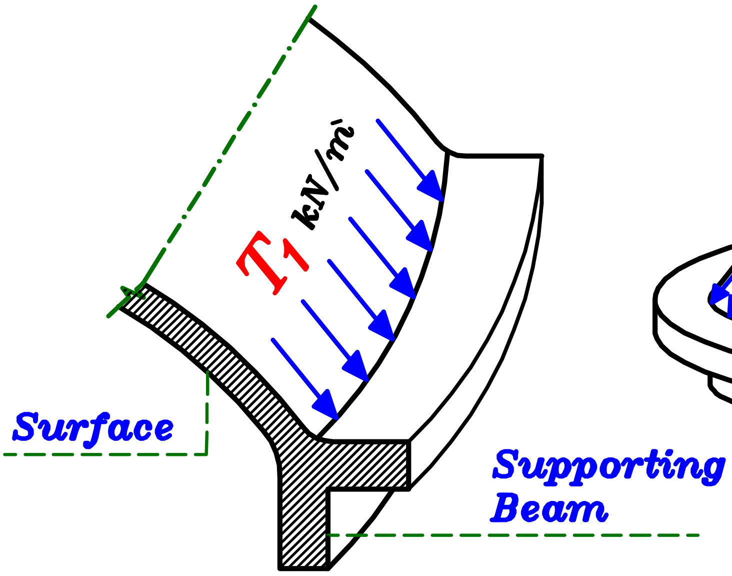
IF T_1 $(+Ve)$ $\longrightarrow$ Comp.

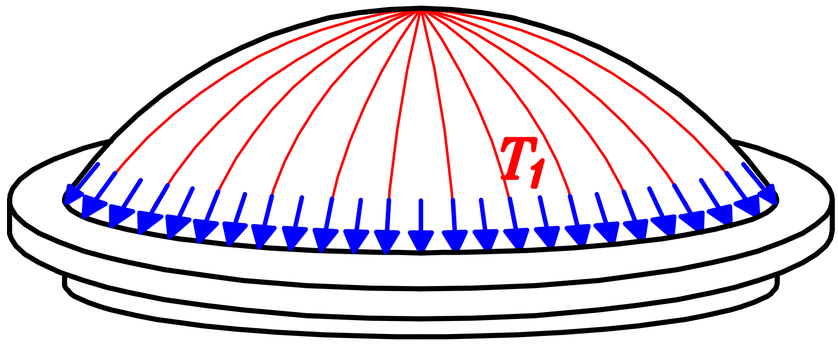


IF T_1 $(-Ve)$ $\longrightarrow$ Ten.



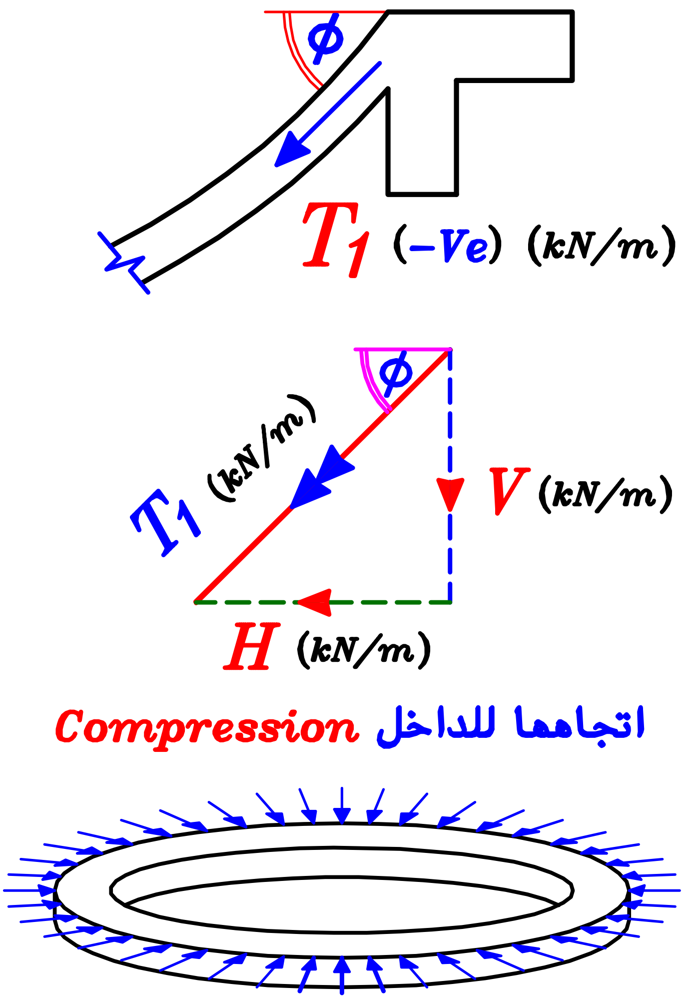
Case (a) IF supporting beam consist of (VL. & HL. Beams).

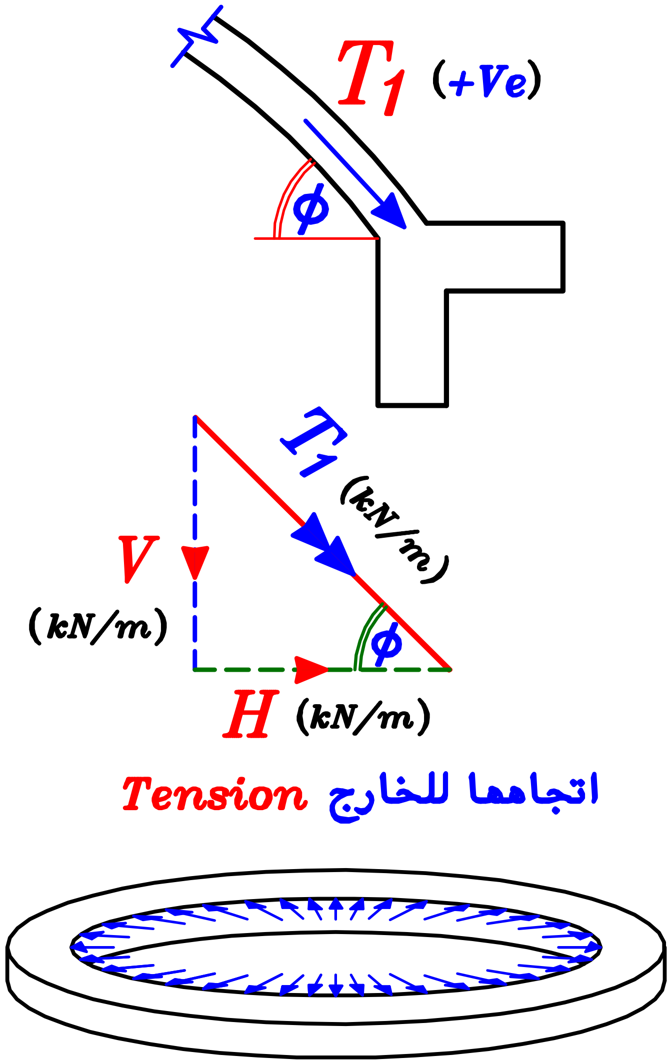




نقوم بتحليل (T_1) الى مركبتين : ١- مركبه رأسيه فى اتجاه (VL. Beam)

٢- مركبه أفقيه فى اتجاه (HL. Beam)

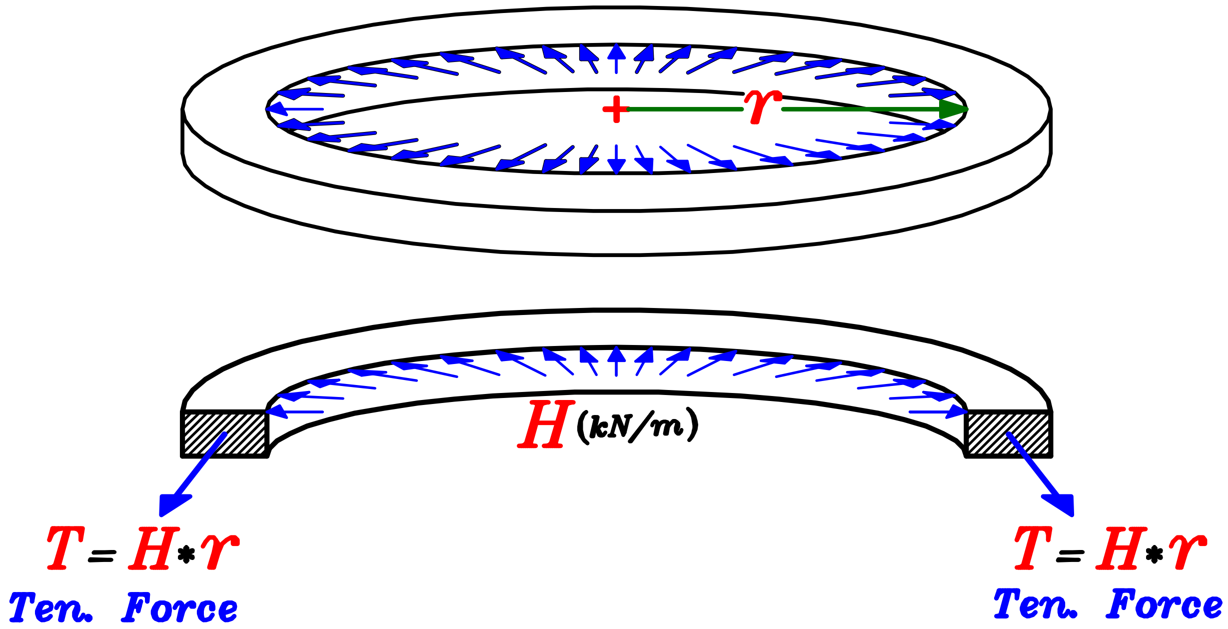


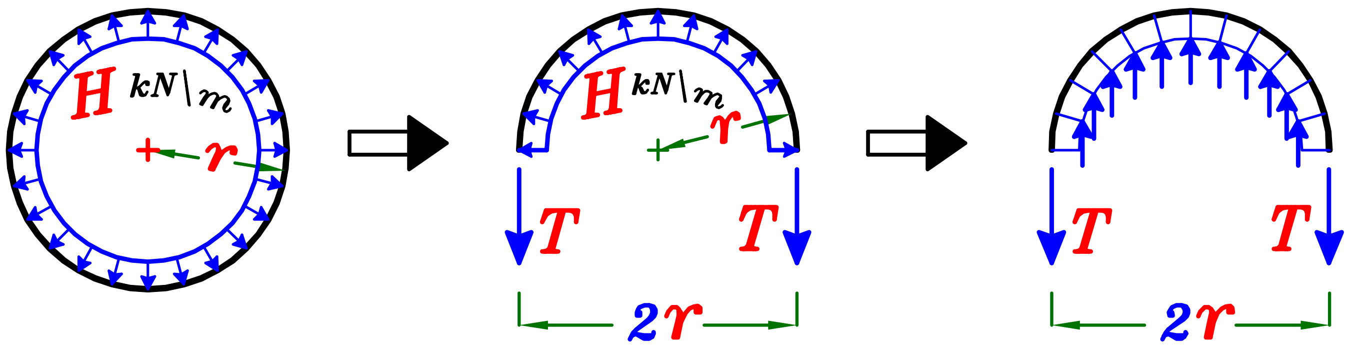


Design of HL. Beam.

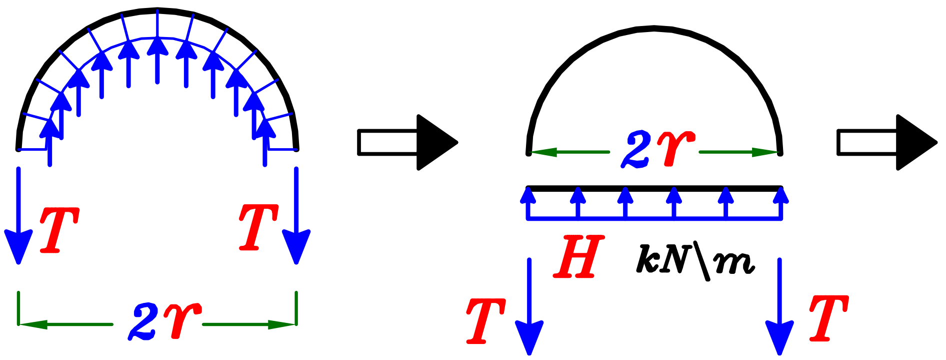
المركبه الافقيه للقوه (T_1) و هى (H) (kN/m) تنتقل الى ال HL. Beam
على شكل Normal Force ضغط أو شد يؤثر على قطاع الكمره .

1 – IF (H) is Tension Force.





بتحليل كل القوى فى اتجاه T



$$2\,T = H * 2\,r$$

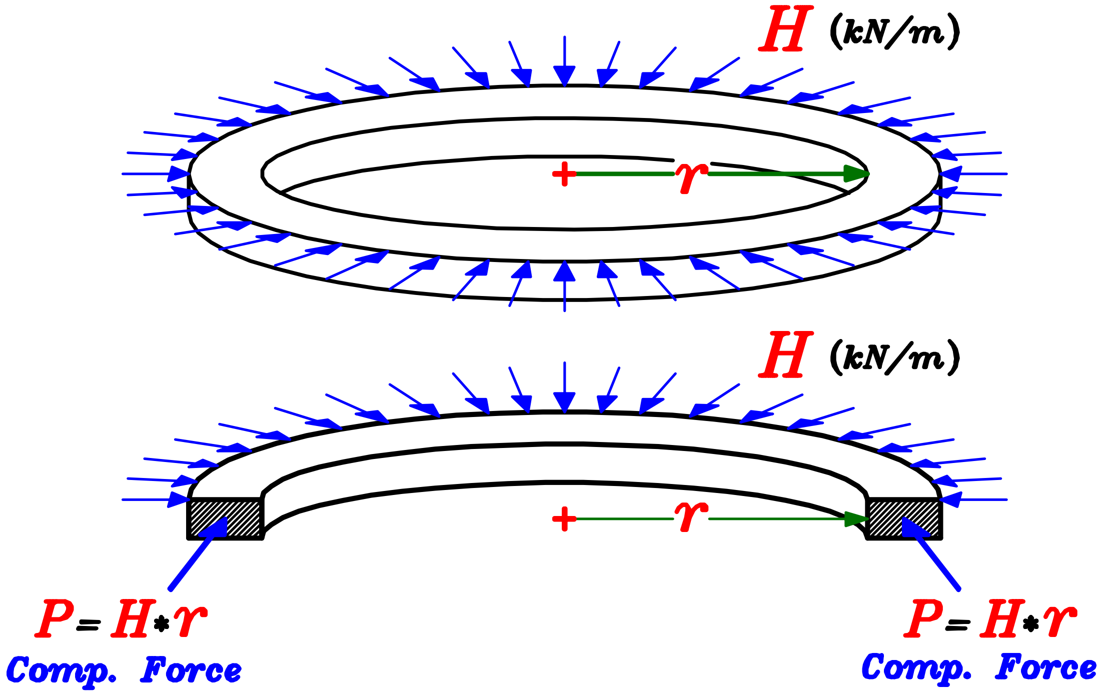
$$\boxed{T = H * r} \text{ kN}$$

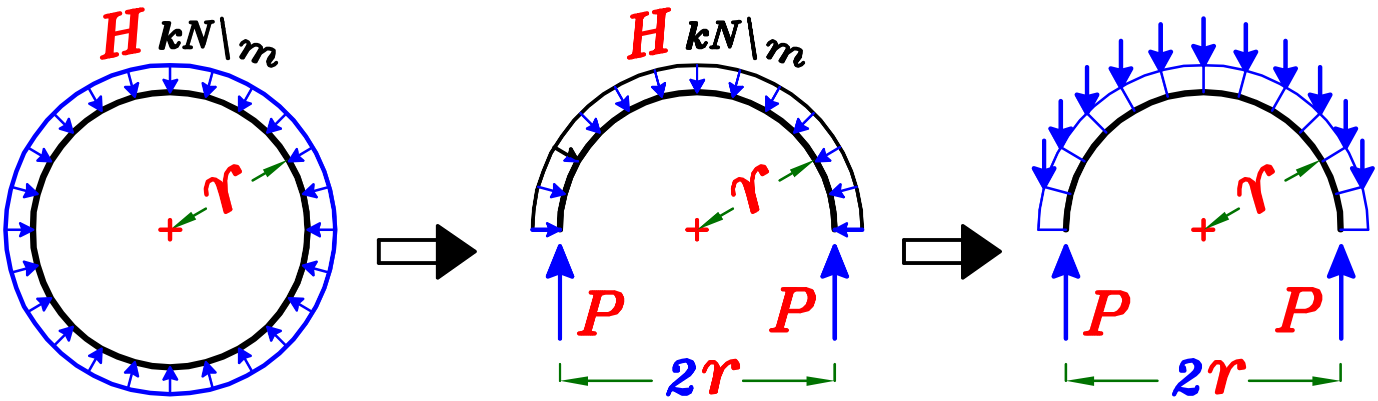
Tension

Design the HL. Beam as a Tie.

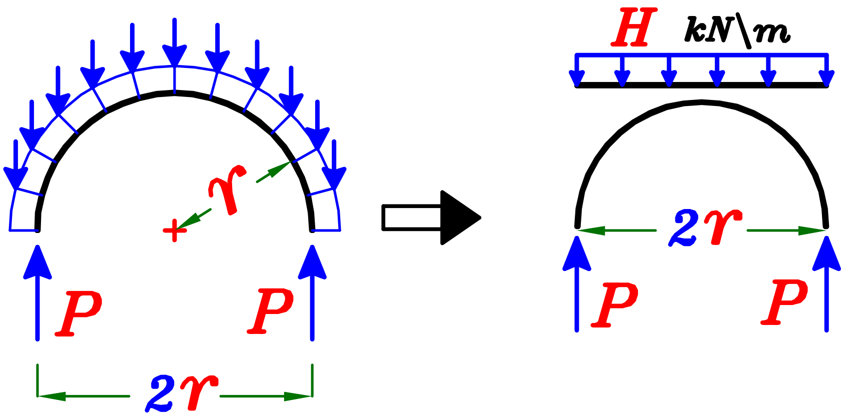
$$\boxed{A_s = \frac{T * 1.5}{F_y / \gamma_s}}$$

2- IF (H) is Compression Force.





بتحليل كل القوى فى اتجاه P



$$2P = H * 2r$$

$$\boxed{P = H * r} \ kN$$

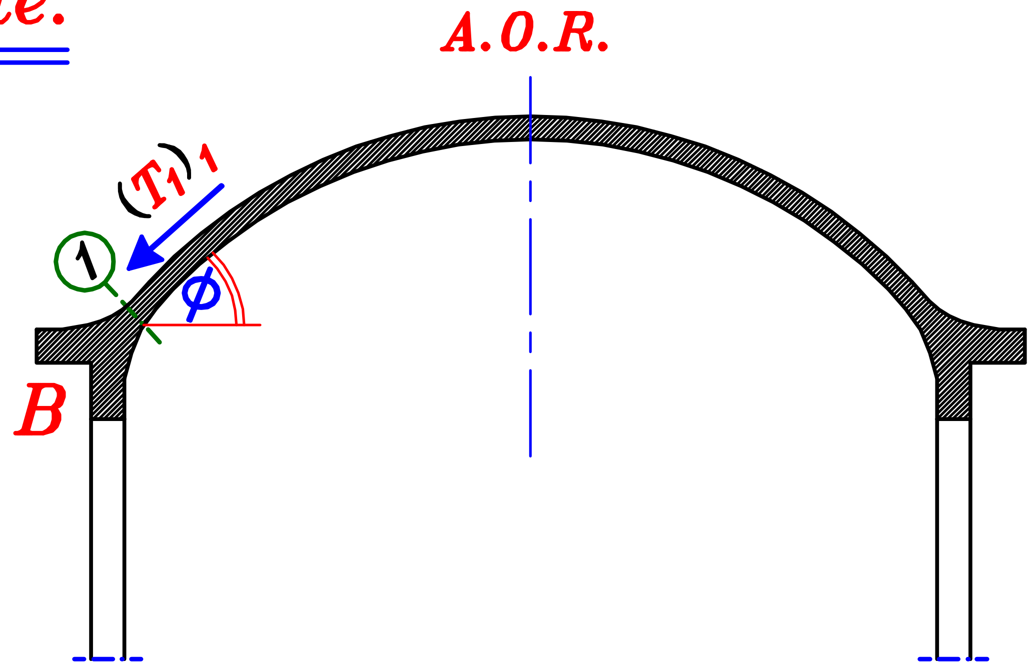
Compression

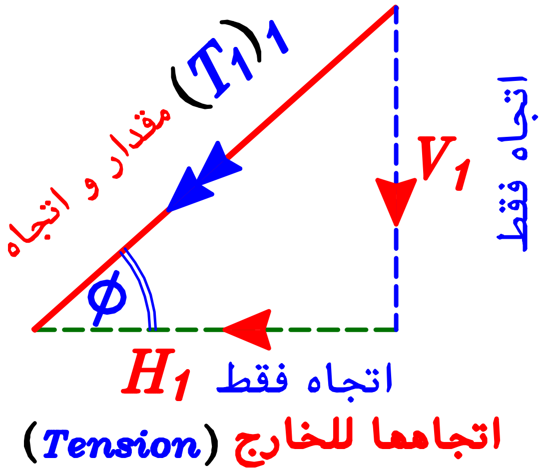
Design the HL. Beam as short Column

$$P_{U.L.} = P * 1.5 = 0.35\ A_c\ F_{cu} + 0.67\ A_s\ F_y \xrightarrow{Get} A_s$$

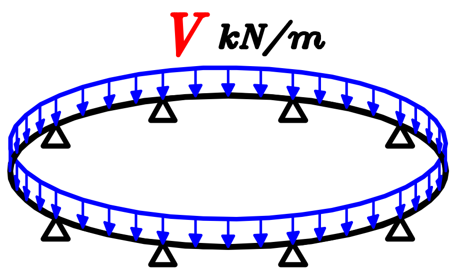
Check $A_{s_{min.}} = \frac{0.80}{100} * A_c$

Example.





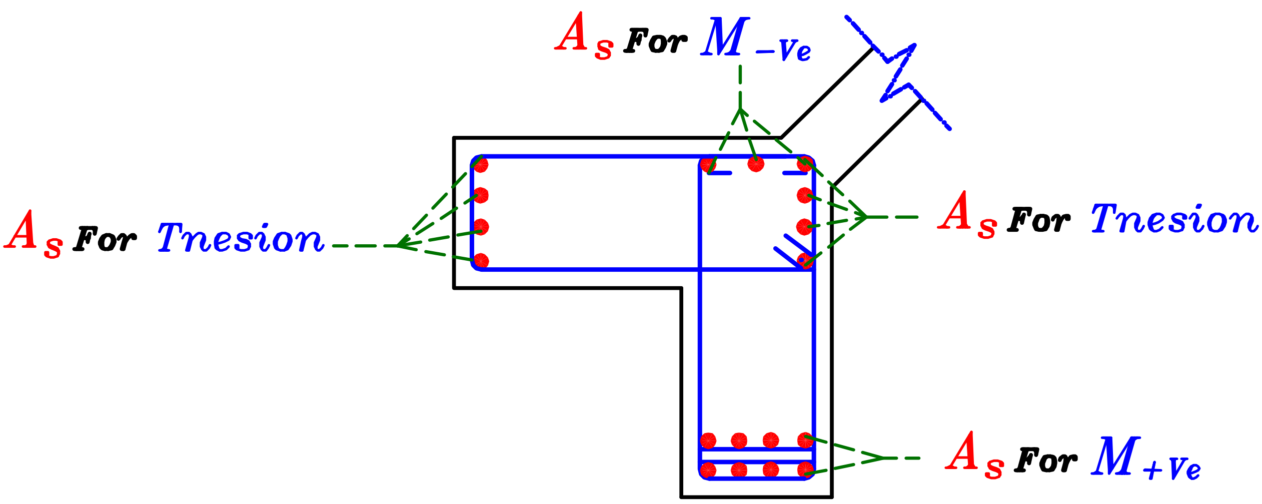
$\boxed{V = V_1 + o.w._{(beam)}}$ (kN/m)



$\boxed{H = H_1}$ (Tension) (kN/m)

$\therefore$ Design the VL. Beam on (B.M. & Q & M_t) due VL. load (V)

Design the HL. Beam on (Normal Tension) due HL. load (H)



Case (b) IF supporting beam consist of (VL. Beam only).

نقوم بتحليل (T_1) الى مركبتين : مركبه رأسيه (V) و مركبه أفقيه (H)

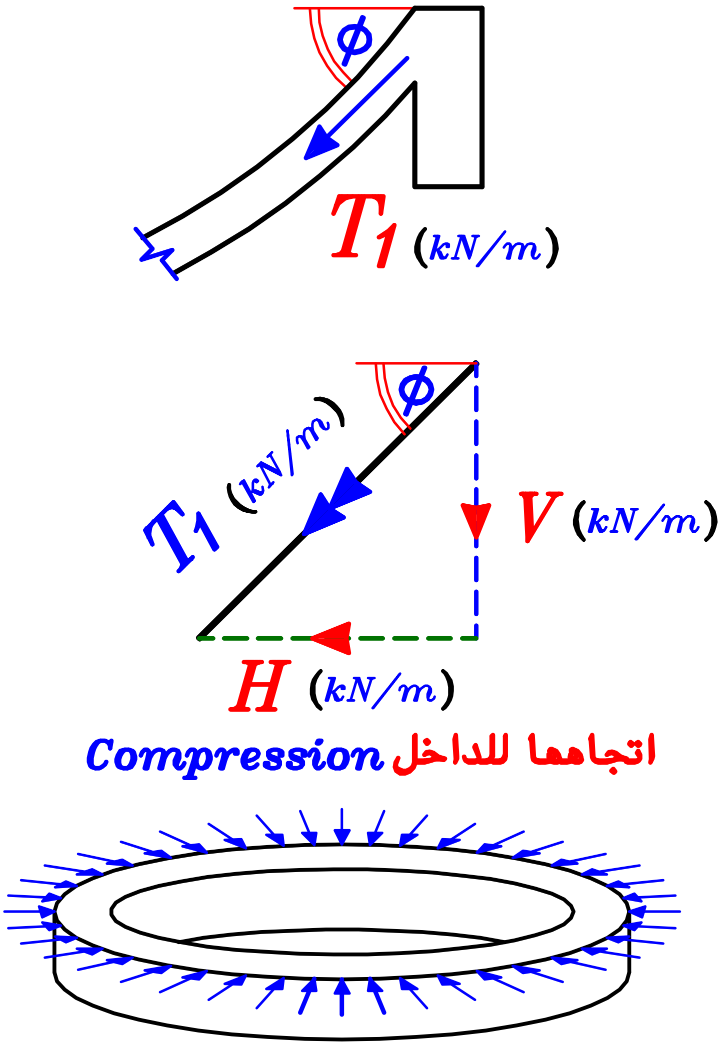
المركبتين ستؤثران على الـ (VL. Beam)

المركبه الرأسيه (V)

مسببه على الكمره الرأسيه Bending Moment , Shear Force & Torsional Moment

المركبه الافقيه (H)

مسببه على الكمره الرأسيه Normal Force اما Tension او Compression .

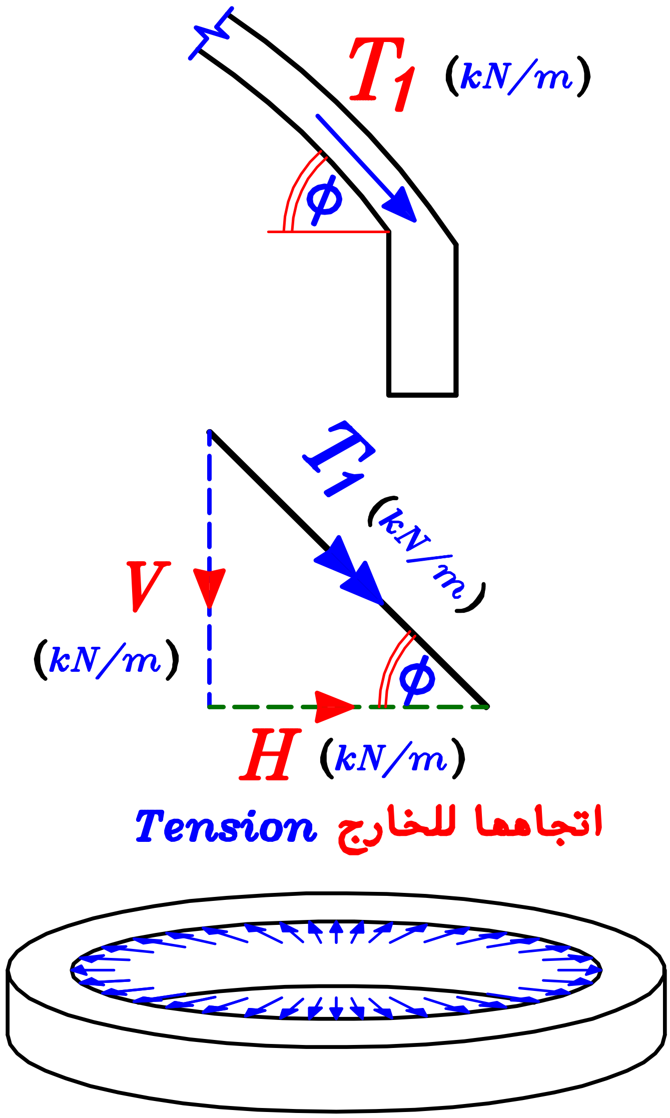


Get $M_{(-ve)}$, $M_{(+ve)}$, Q , M_t

From old Tables Page 120

Design the VL. Beam on

(M, P) & (Q, M_t)



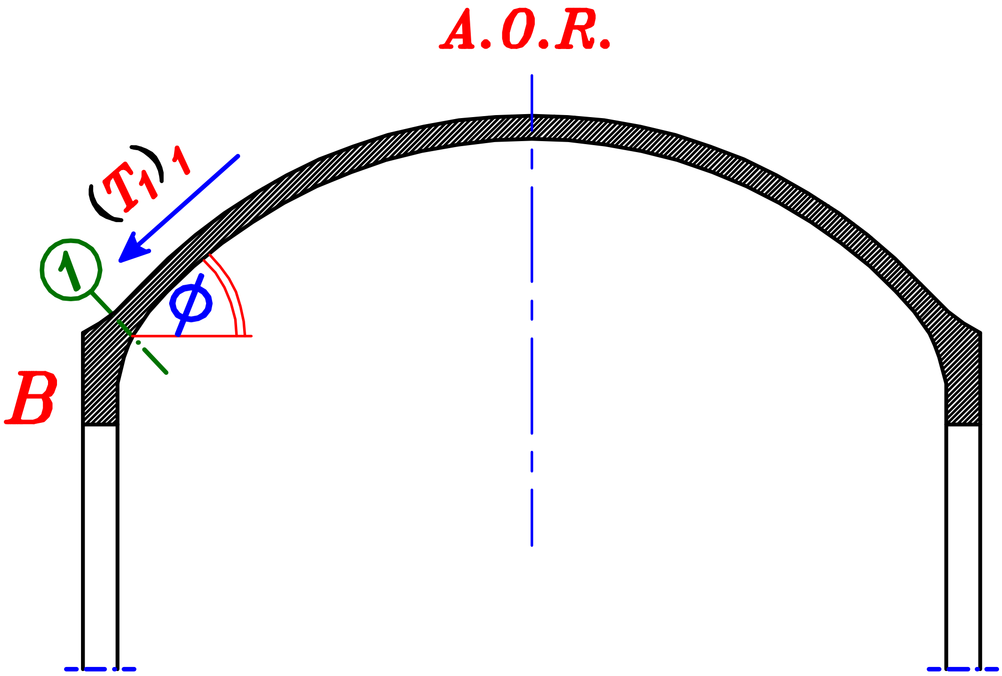
Get $M_{(-ve)}$, $M_{(+ve)}$, Q , M_t

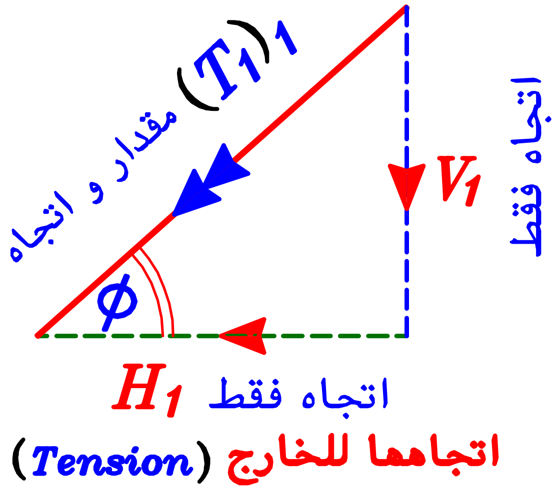
From old Tables Page 120

Design the VL. Beam on

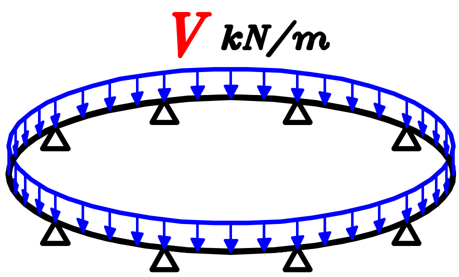
(M, T) & (Q, M_t)

Example.





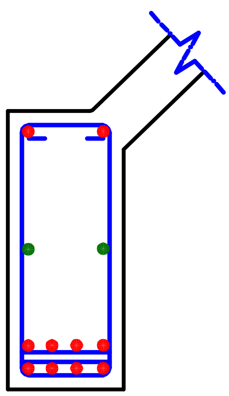
$$\boxed{V = V_1 + o.w._{(beam)}} \quad (kN/m)$$



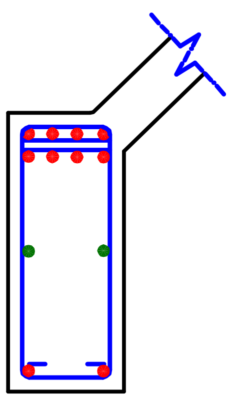
$$\boxed{H = H_1} \quad (Tension) \quad (kN/m)$$

$\therefore$ Design the Beam on (B.M. & Tension)

Design the Stirrups on (Q & M_t)



Sec. at mid Span



Sec. at Support

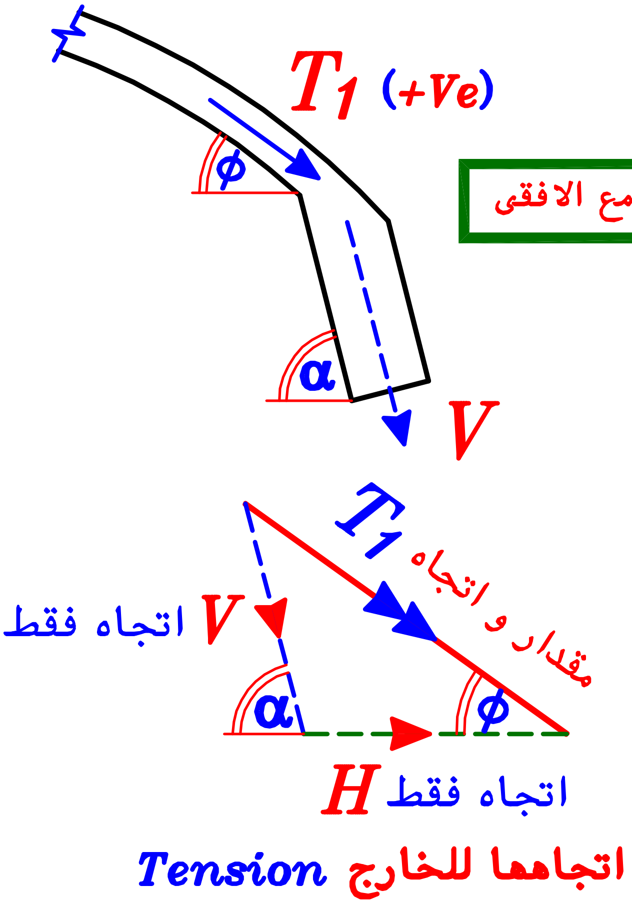
Case (c) IF supporting beam consist of (Inclined Beam only).

فى حاله ما اذا كانت الكمره مائله بزاويه (α) مع الافقى .

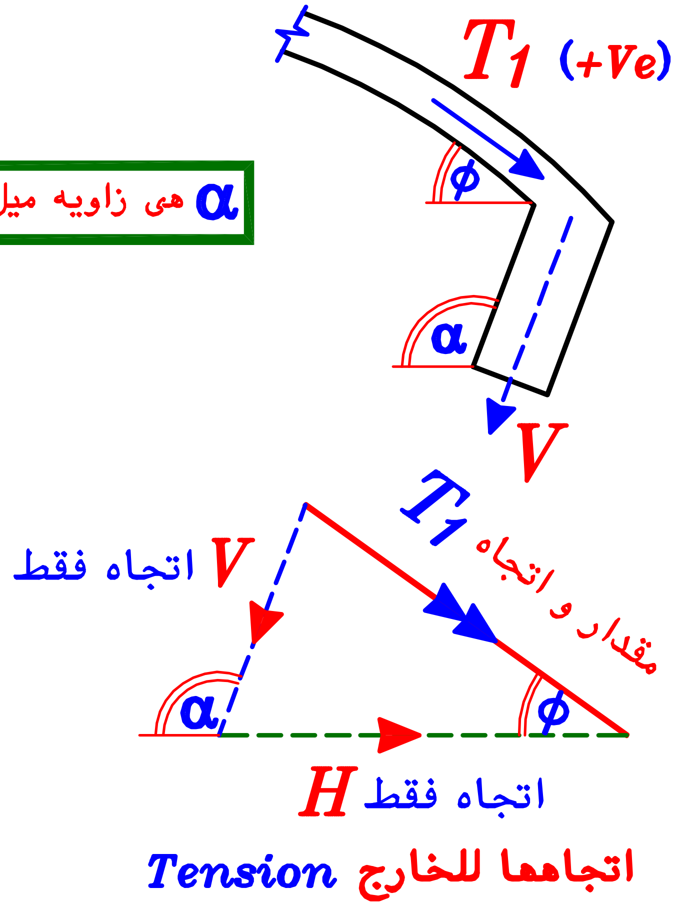
فانه يتم تحليل القوه (T_1) الى مركبتين : مركبه فى اتجاه الكمره (V) و مركبه أفقيه (H)

المركبه فى اتجاه الكمره (V) ستسبب $(B.M.\ \&\ Q\ \&\ M_t)$ على الكمره .

المركبه الافقيه (H) ستسبب $(Normal)$ اما Tension او Compression .



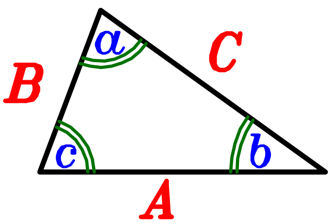
α هى زاويه ميل الكمره مع الافقى



لتحديد قيمه كلا من $H \& V$ نستخدم احدى الطريقتين :

١– نستخدم Sin Rule

Sin Rule



$$\frac{A}{\sin a} = \frac{B}{\sin b} = \frac{C}{\sin c}$$

$$a + b + c = 180^\circ$$

٢– نرسم خط لـ (T_1) بـ scale مناسب (مقدار و اتجاه) ثم نرسم خط موازى للكمره من بدايه خط (T_1) (اتجاه فقط)

ثم نرسم خط افقى من نهايه خط (T_1) حتى يتقاطع مع الخط الموازى للكمره ثم نقيس طول كلا من الخطين

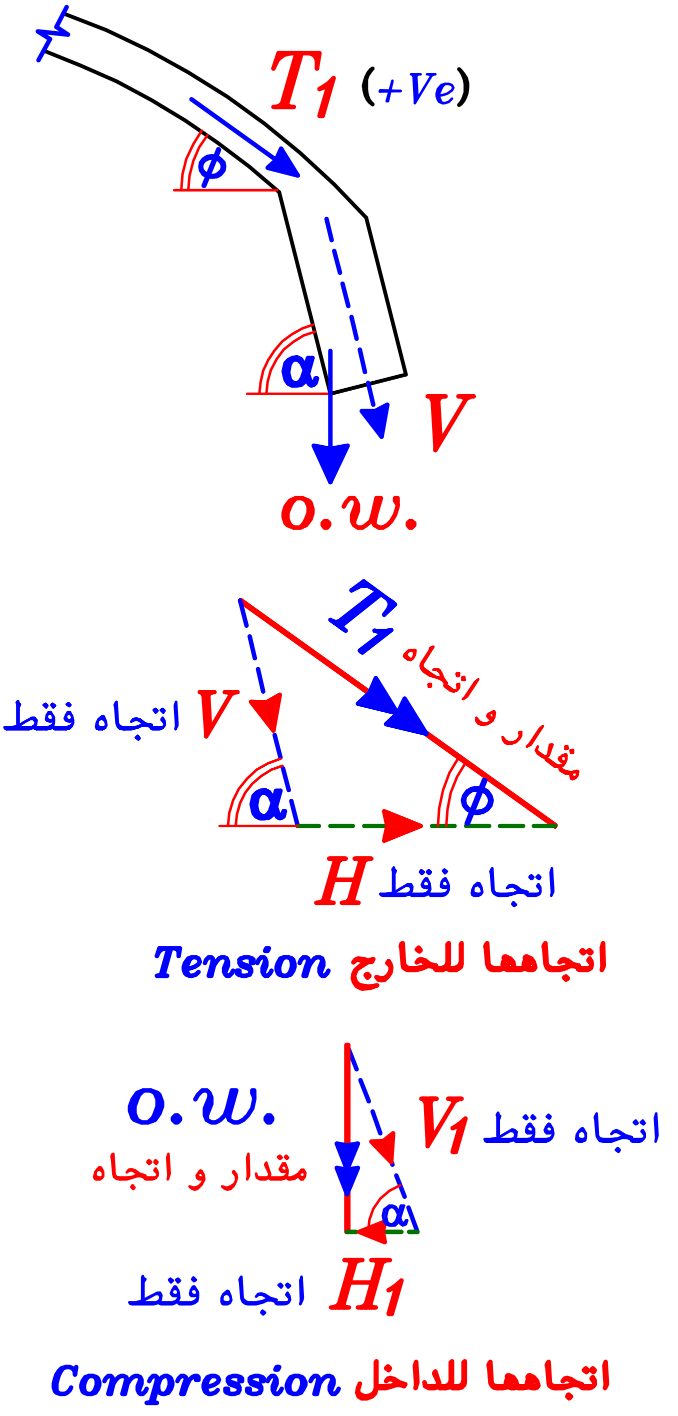
الخط الافقى و الخط الذى فى اتجاه الكمره بنفس الـ scale المرسوم به (T_1) فتكون قيمتى $H \& V$

بعد تحديد قيمه و اتجاه مركبات (T_1) و هما V, H

يجب تحديد قيمه و اتجاه مركبات وزن الكمره $(o.w.)$ و هما V_1 , H_1

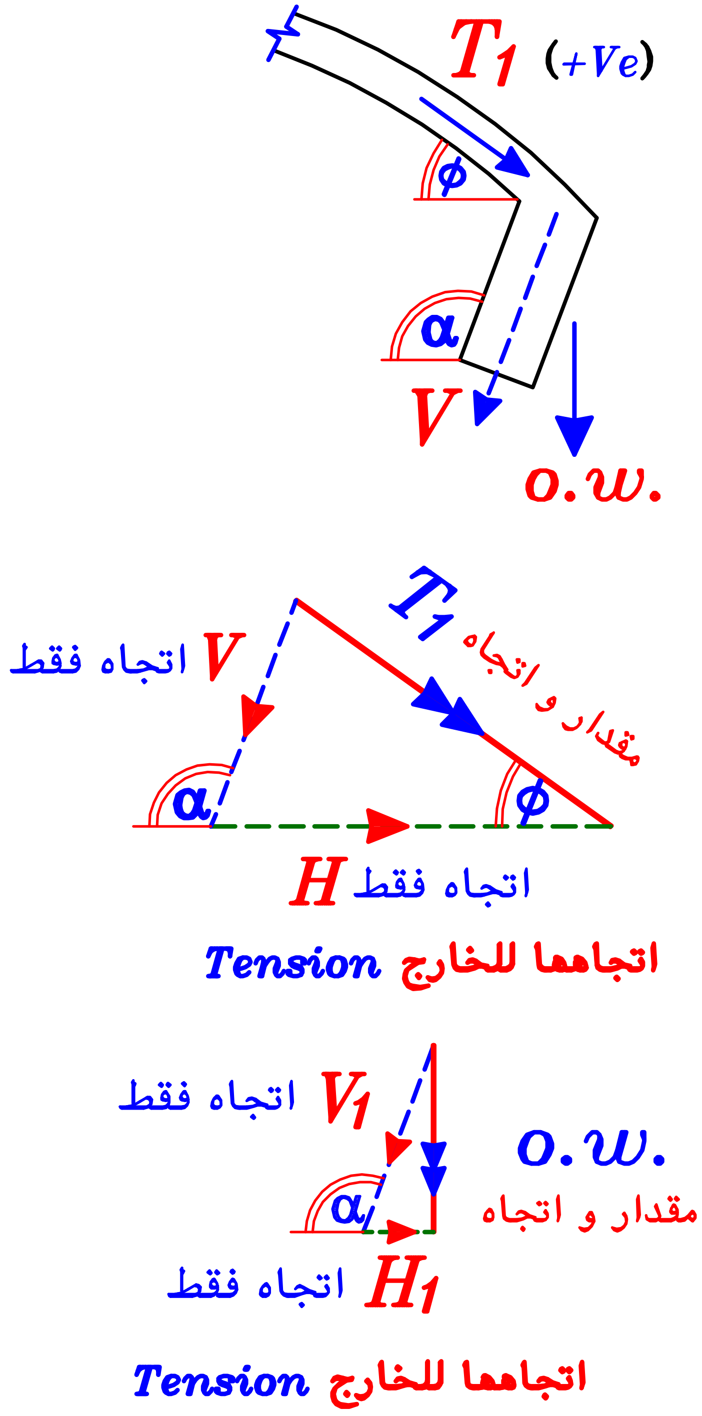
ثم نحدد قيمه و اتجاه مركبات القوى فى اتجاه الكمره (V_{total})

و قيمه و اتجاه مركبات القوى فى الاتجاه الافقى (H_{total})



$$V_{total} = V + V_1 \quad (kN/m)$$

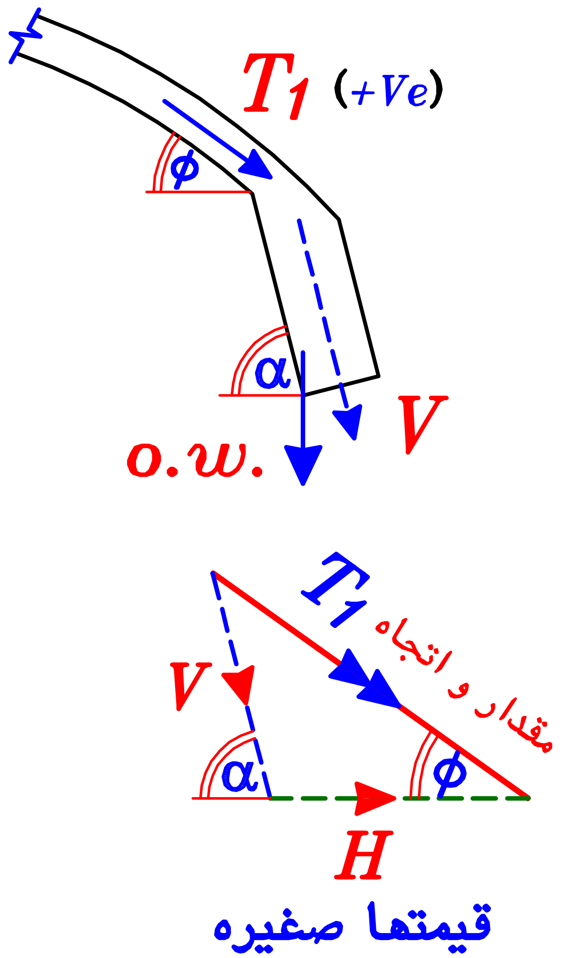
$$H_{total} = H - H_1 \quad (kN/m)$$

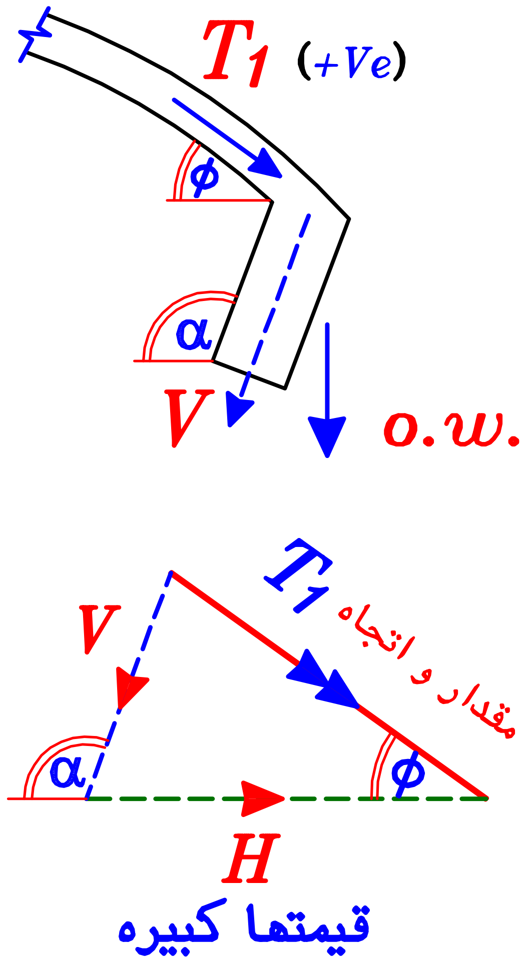


$$V_{total} = V + V_1 \quad (kN/m)$$

$$H_{total} = H + H_1 \quad (kN/m)$$

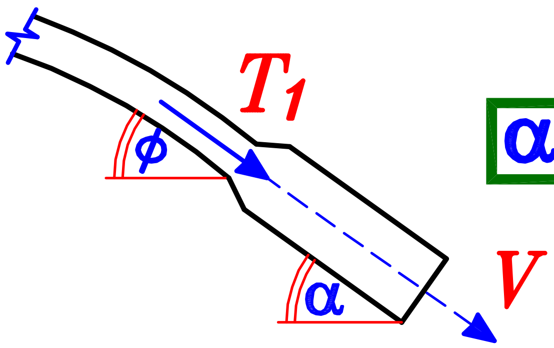
ملحوظه :





لاحظ أنه عندما كان ميل الكمره مقارب لميل السطح اى ميل (T_1) ستكون قيمه المركبه الافقيه H صغيره أى ان قيمه الـ ***Normal Force*** المؤثره على الكمره صغيره .
بينما عندما يكون ميل الكمره بعيدا عن ميل (T_1) ستكون قيمه المركبه الافقيه H كبيره أى ان قيمه الـ ***Normal Force*** المؤثره على الكمره كبيره .

اذاً افضل اتجاه نختاره للكمره هو ان يكون ميل الكمره (α) هو بالضبط نفس ميل (T_1) أى أن $\alpha = \phi$ حتى لايوجد مركبه أفقيه H و بالتالى لا يوجد ***Normal Force*** على الكمره



$$\boxed{\alpha = \phi}$$

$$\boxed{V = T_1}$$

Intersection between two surfaces.

When two surfaces intersect , there will be one of two cases.

عند تقاطع سطحين تكون هناك حاله من اثنين :

1– Case of two surfaces on the same supporting beam.

توجد كمره تحمل السطحين عند نقطه تقاطعهم .

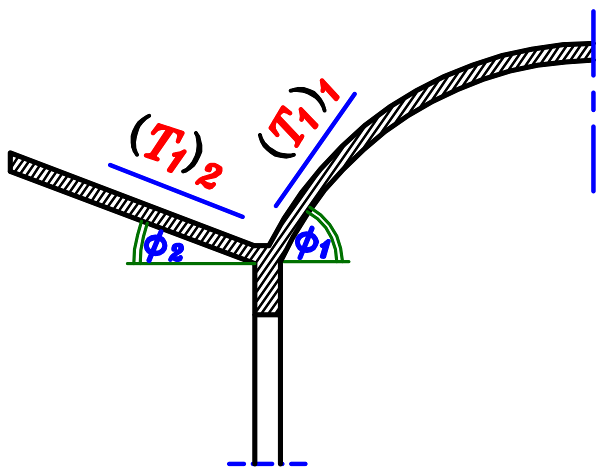
لتحديد اتجاه (T_1) لكل سطح على الكمره .

نحدد لكل سطح محمول على الكمره اشاره (T_1) اذا كانت $(+Ve)$ أم $(-Ve)$

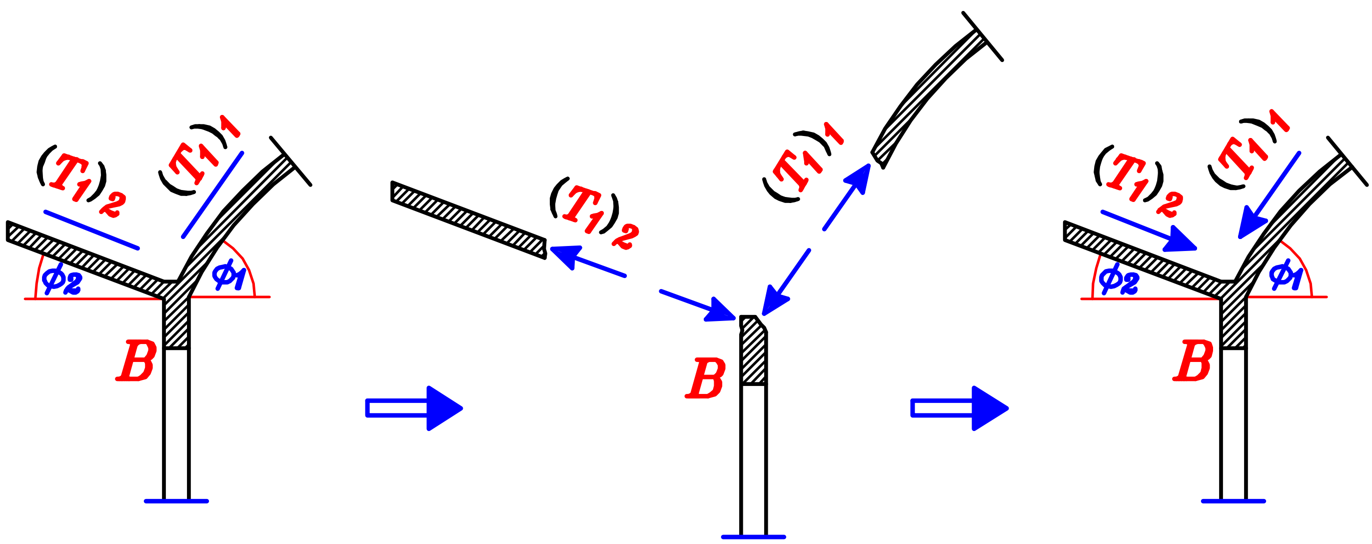
و نحدد اتجاهها على السطح و منه نعكس الاتجاه على الكمره .

Example.

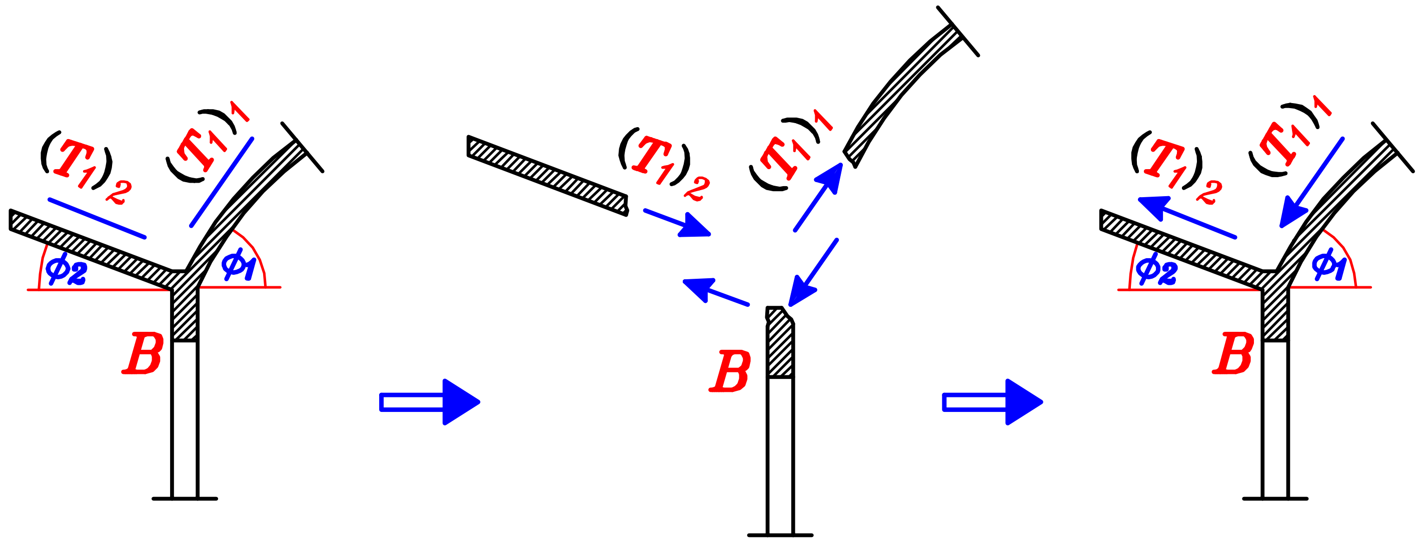
Get $(T_1)_1$ & $(T_1)_2$ Directions to the beam.



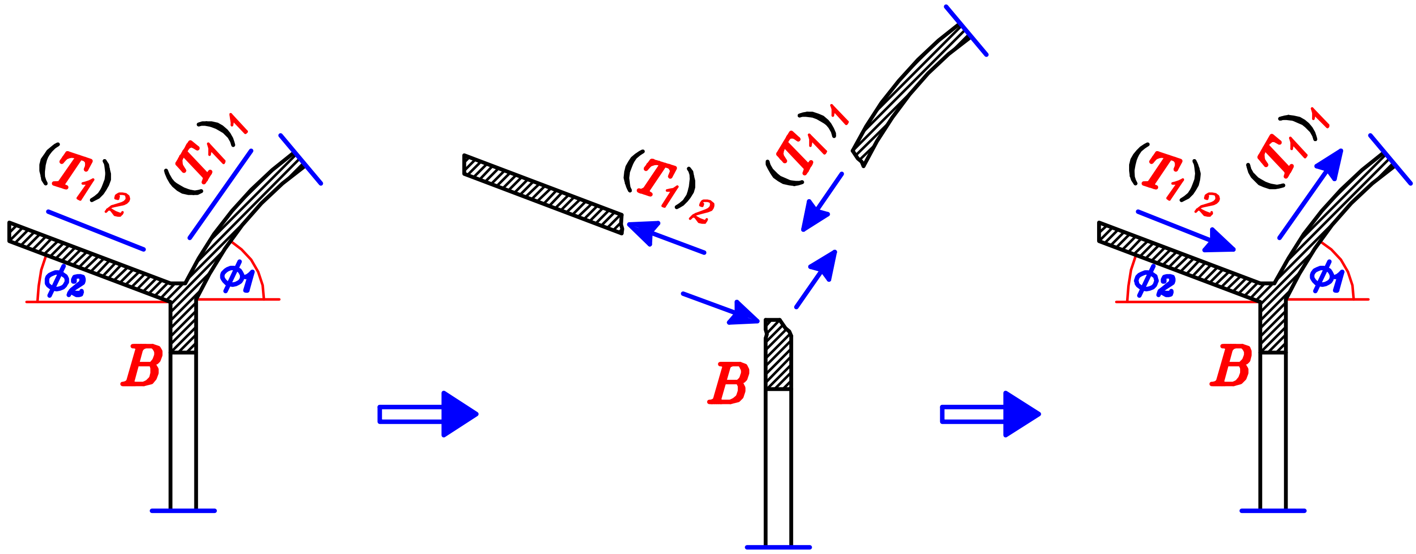
IF $(T_1)_1$ (+Ve) ⟶ Comp. & $(T_1)_2$ (+Ve) ⟶ Comp.



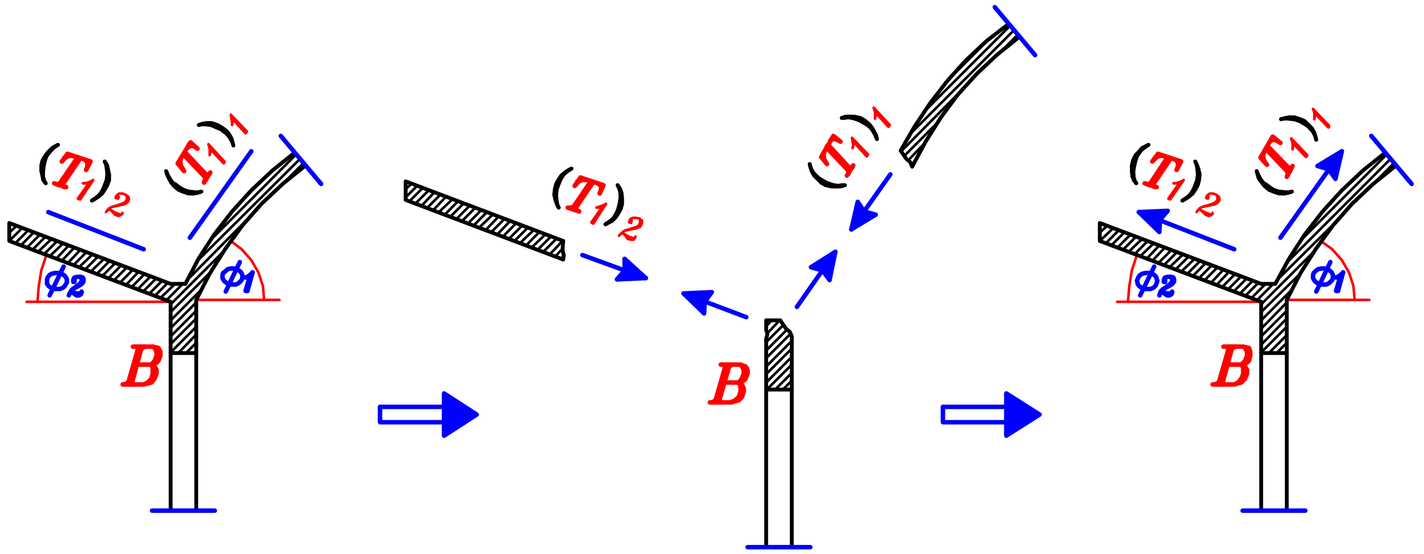
IF $(T_1)_1$ (+Ve) → Comp. & $(T_1)_2$ (−Ve) → Ten.



IF $(T_1)_1$ (−Ve) → Ten. & $(T_1)_2$ (+Ve) → Comp.

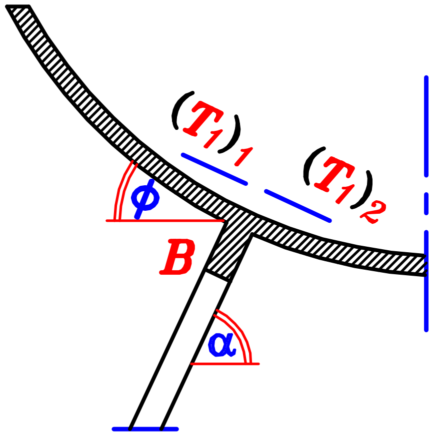


IF $(T_1)_1$ (−Ve) → Ten. & $(T_1)_2$ (−Ve) → Ten.

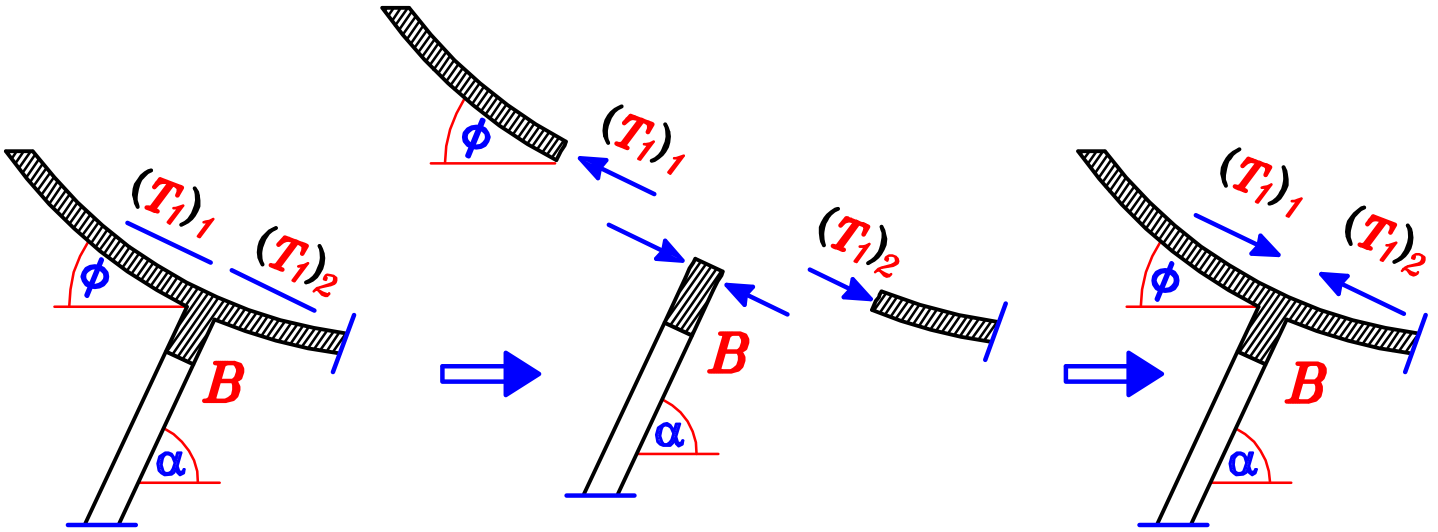


Example.

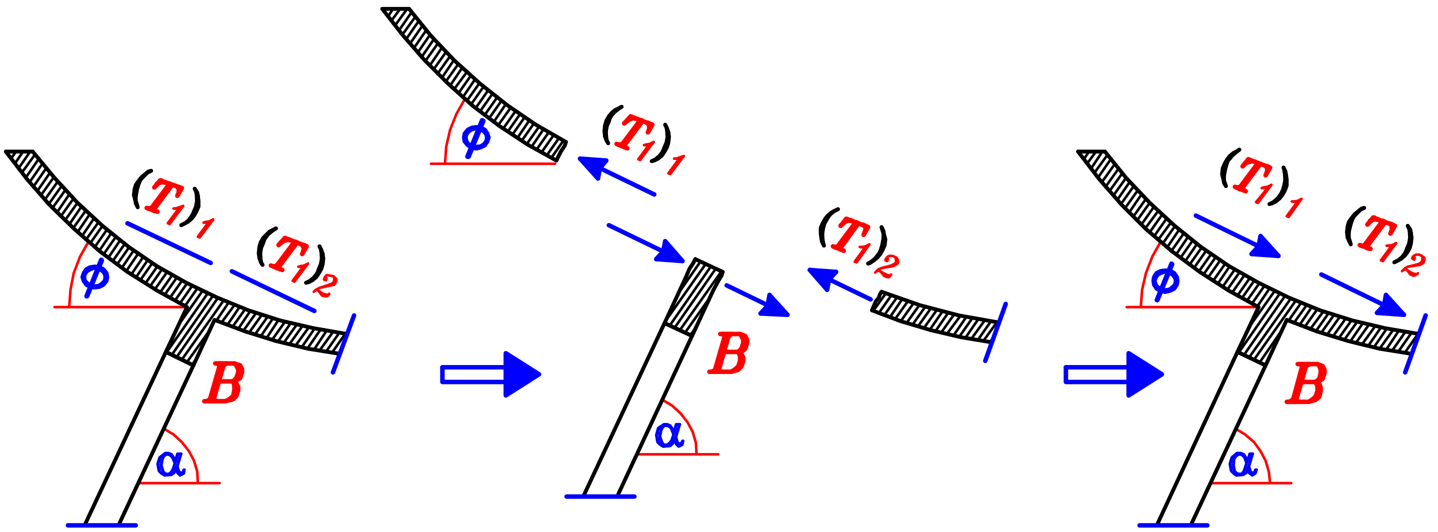
Get $(T_1)_1$ & $(T_1)_2$ Directions to the beam.



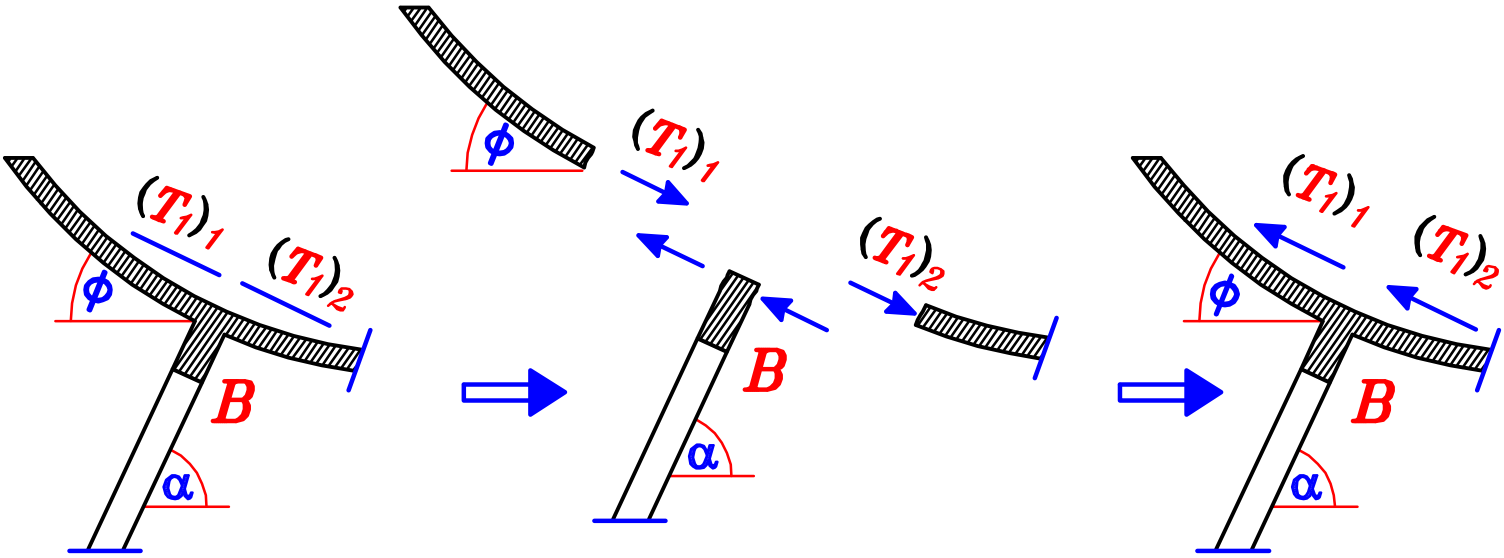
IF $(T_1)_1$ (+Ve) $\longrightarrow$ Comp. & $(T_1)_2$ (+Ve) $\longrightarrow$ Comp.



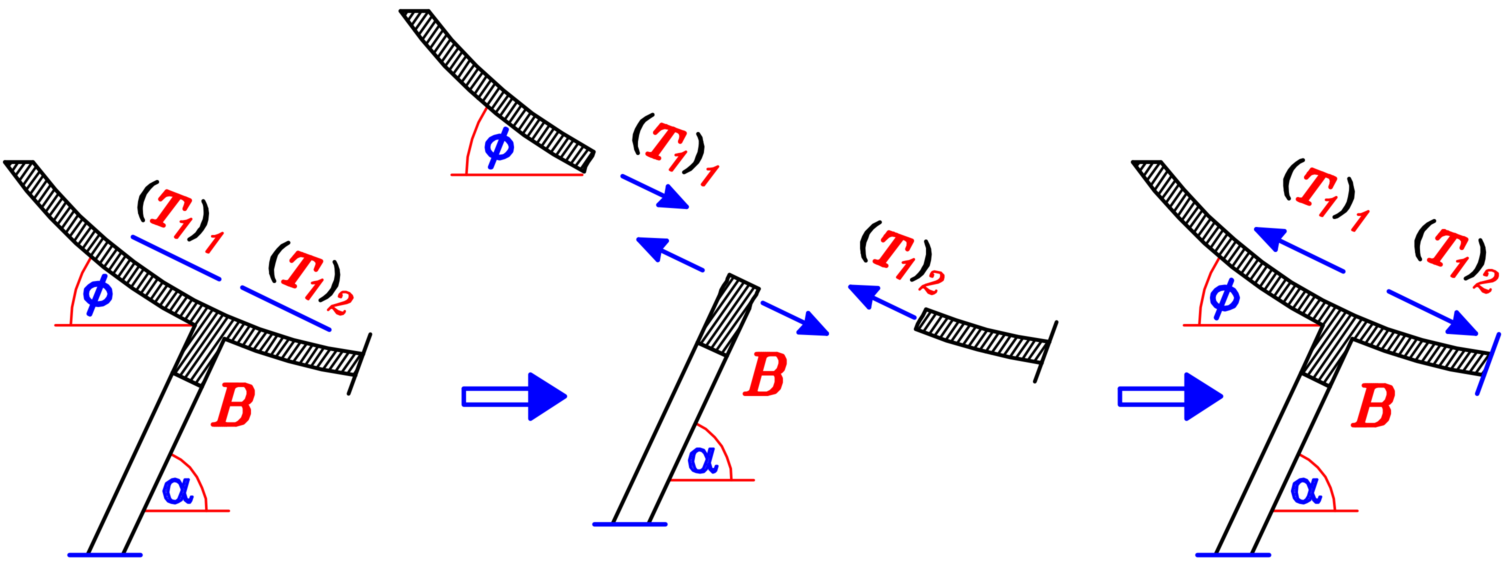
IF $(T_1)_1$ (+Ve) $\longrightarrow$ Comp. & $(T_1)_2$ (−Ve) $\longrightarrow$ Ten.



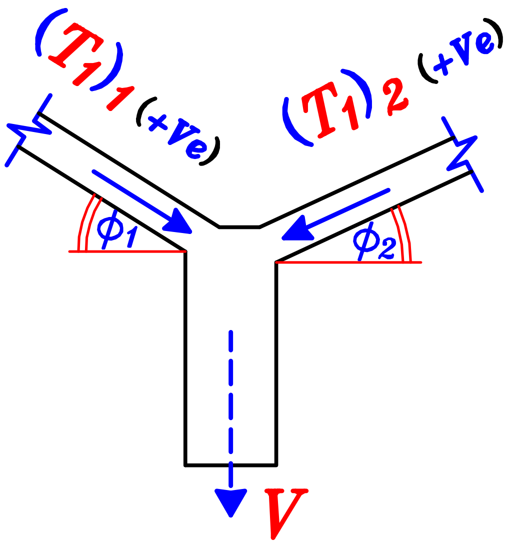
IF $(T_1)_1$ (-Ve) → Ten. & $(T_1)_2$ (+Ve) → Comp.

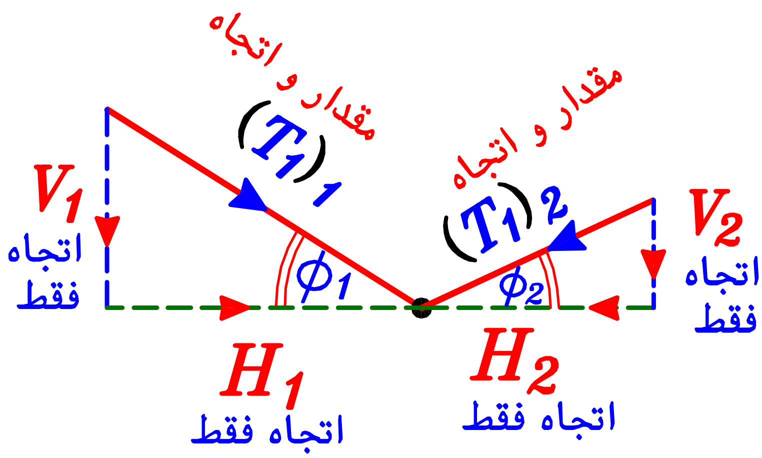


IF $(T_1)_1$ (-Ve) → Ten. & $(T_1)_2$ (-Ve) → Ten.



اذا كان السطحين لهم ميلين عكس بعض





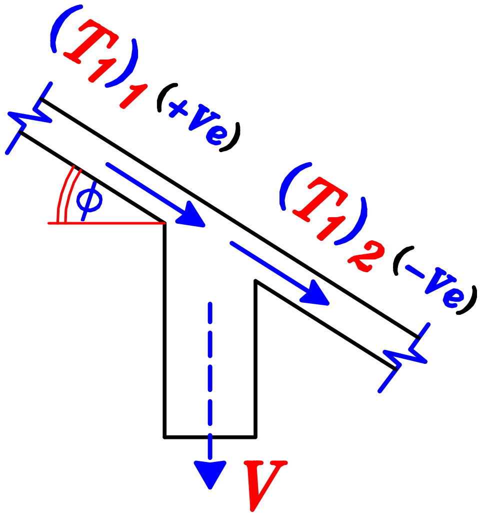
VL. Load on beam =

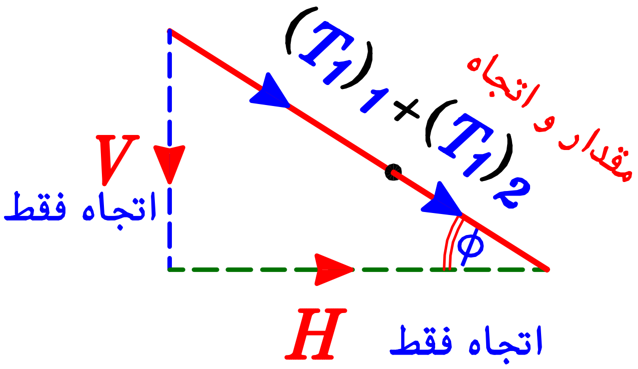
$$w = V_1 + V_2 + o.w._{(beam)} \quad (kN/m)$$

HL. Load on beam =

$$= H_1 - H_2 \quad (kN/m)$$

اذا كان السطحين لهم نفس الميل





VL. Load on beam =

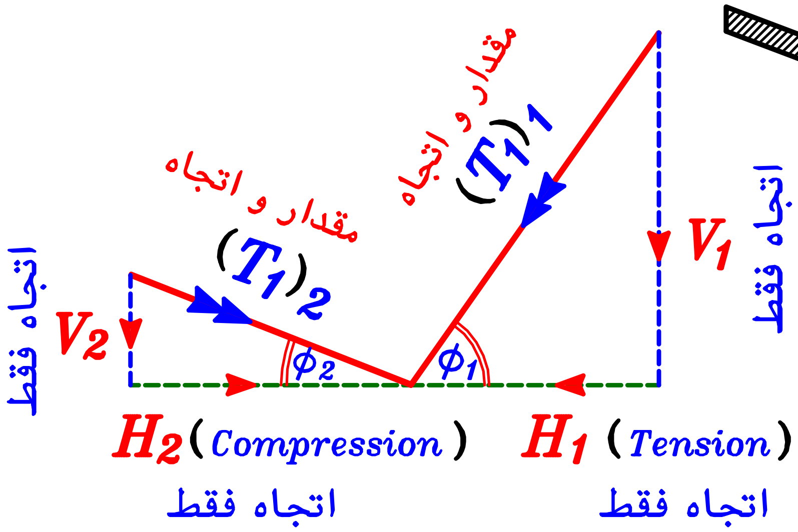
$$w = V + o.w._{(beam)} \quad (kN/m)$$

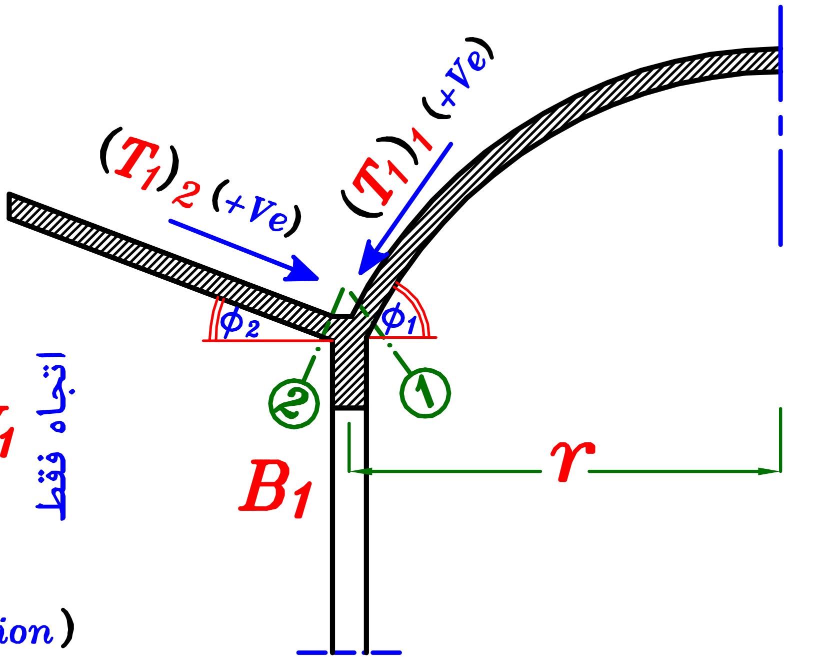
HL. Load on beam =

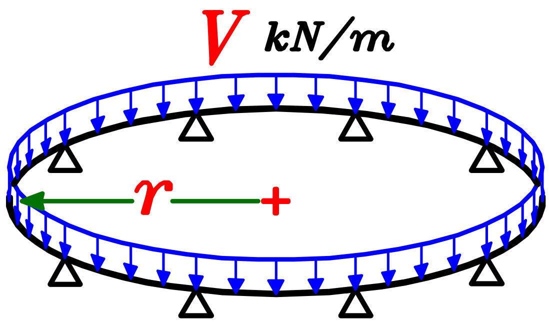
$$= H \quad (kN/m)$$

Example.

B_1





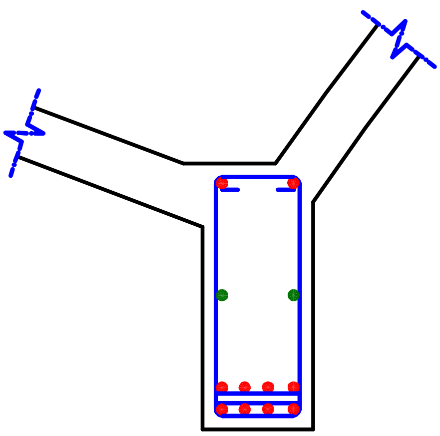


$$V = V_1 + V_2 + o.w._{(beam)} \ (kN/m)$$

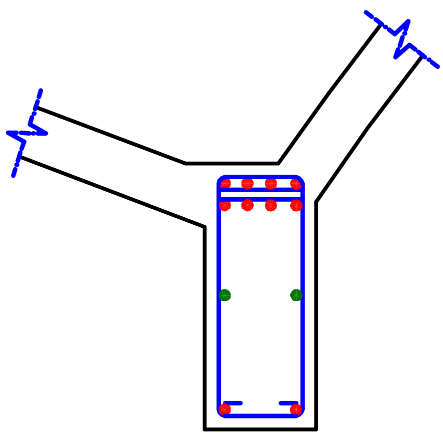
$$H = H_1 - H_2 \quad (kN/m)$$

$$\text{Normal Force} = H * r$$

* IF $H_1 > H_2$ (**Tension**) $\longrightarrow$ Design the Beam on M, T
* IF $H_1 < H_2$ (**Compression**) $\longrightarrow$ Design the Beam on M, P
* IF $H_1 = H_2$ (**No Axial Force**) $\longrightarrow$ Design the Beam on M only



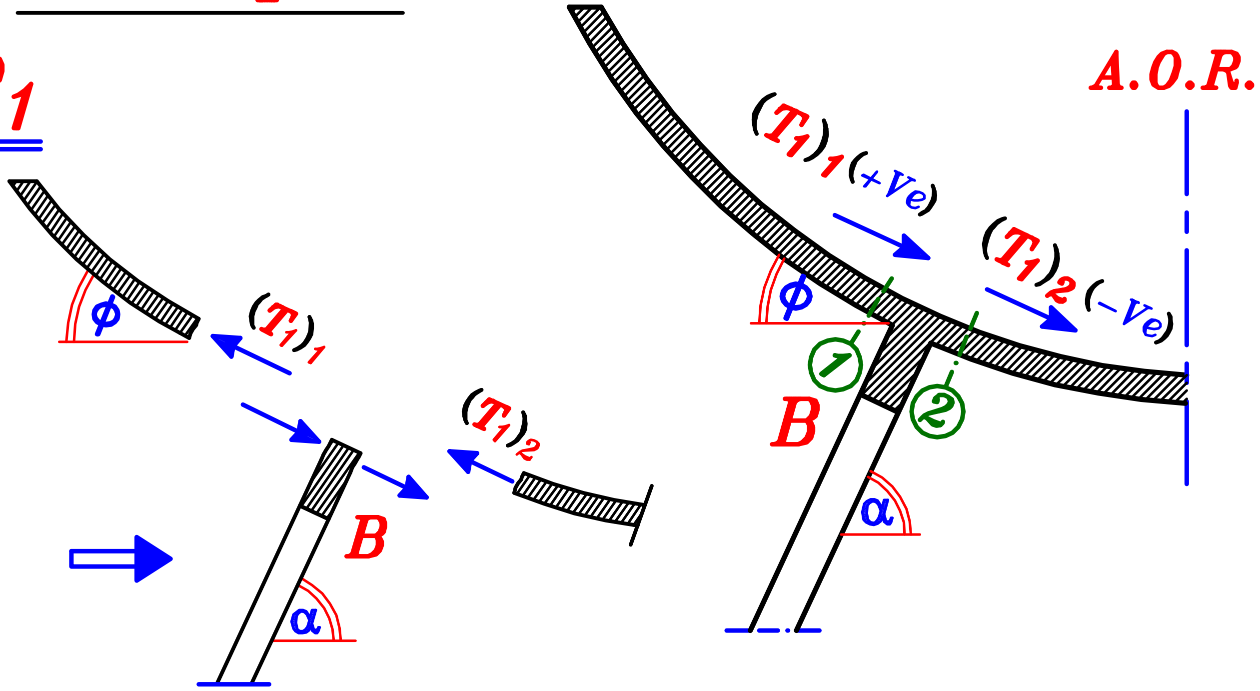
Sec. at mid Span

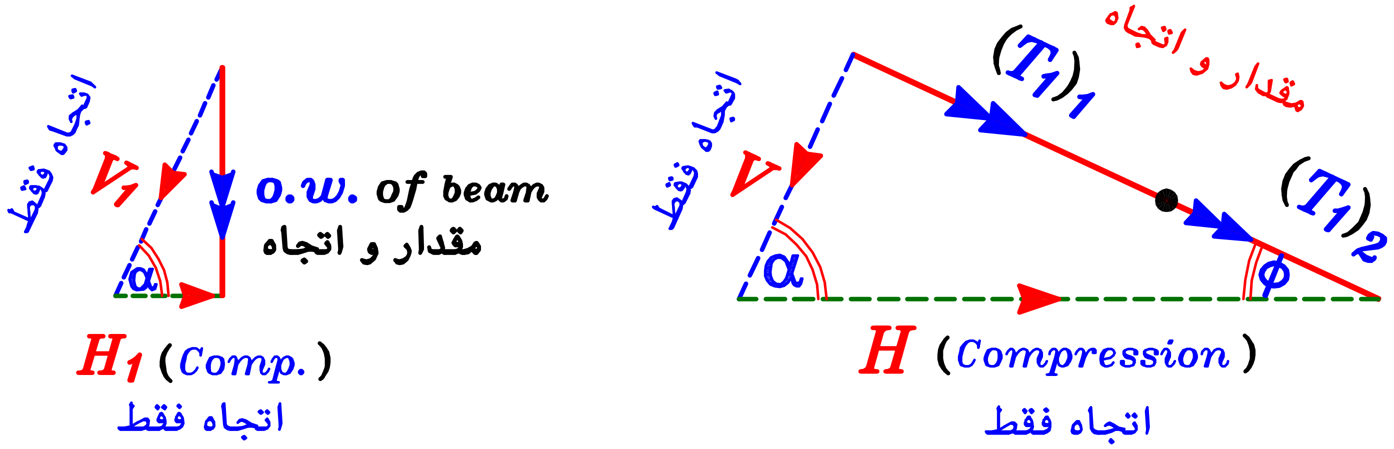


Sec. at Support

Example.

B_1





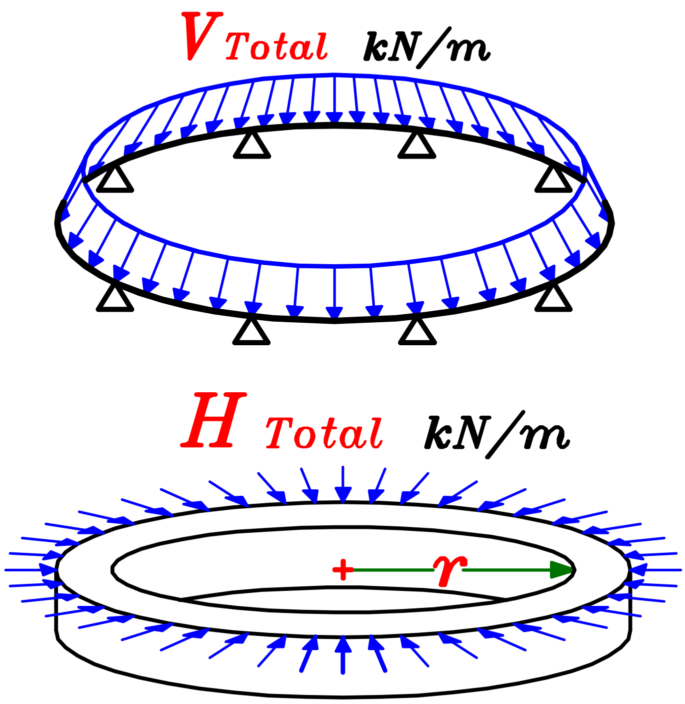
$$\boxed{V_{Total} = V + V_1}$$

Get M_{+Ve} , M_{-Ve}

M_t , $Q_{cor.}$

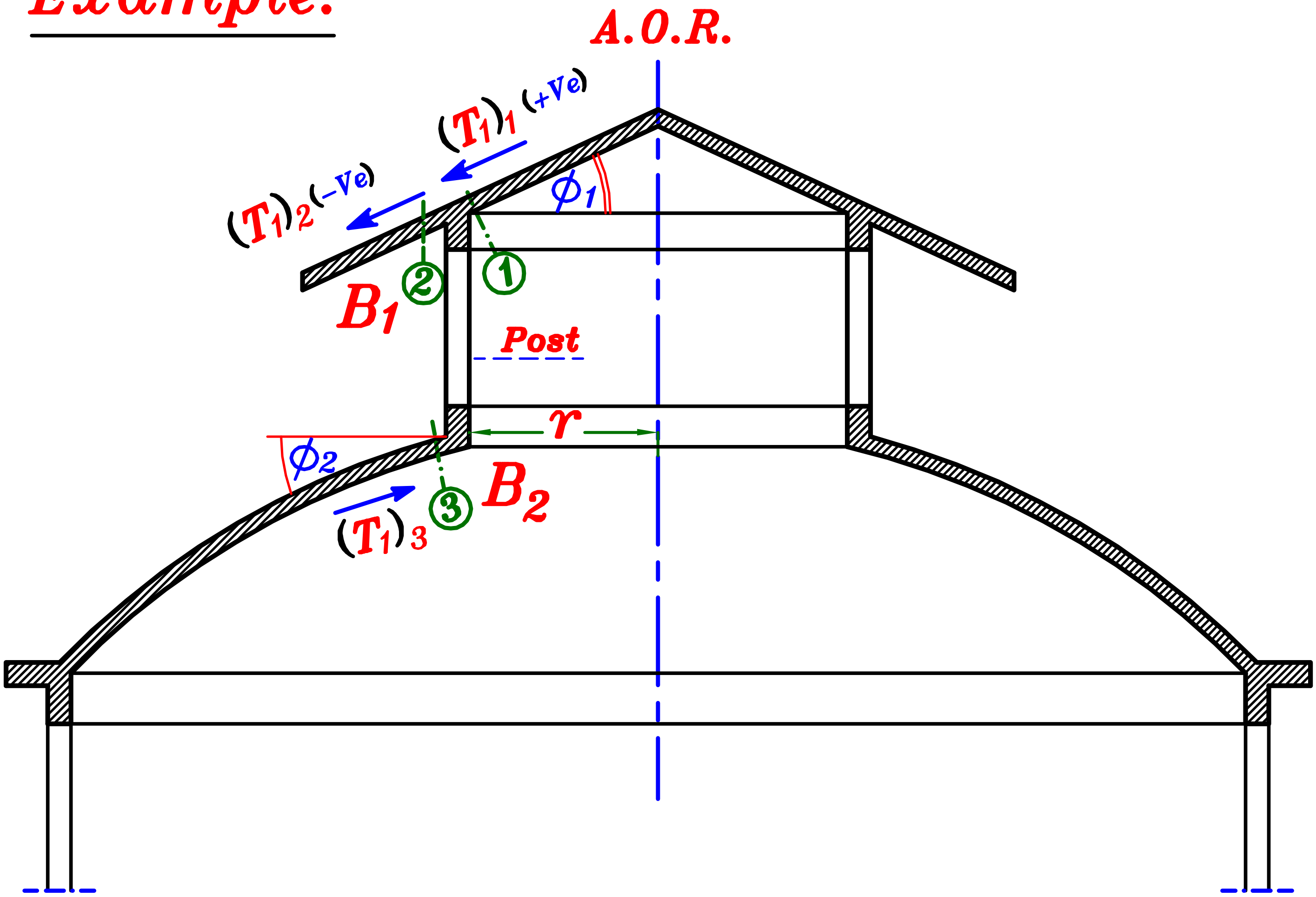
$$\boxed{H_{Total} = H + H_1}$$

$$\boxed{P = H_{Total} * r}$$

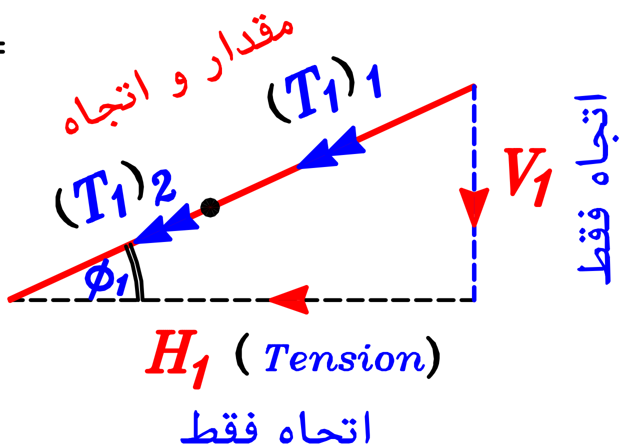


Design the Beam on M , P and M_t , $Q_{cor.}$

Example.



B_1



$$\boxed{w = V_1 + o.w._{(beam)}}$$

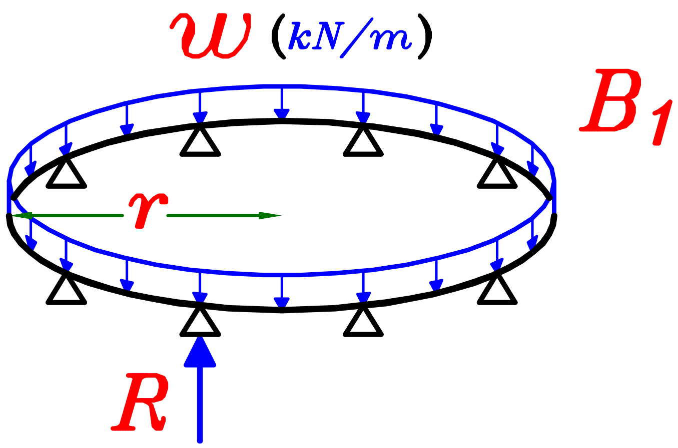
$$\boxed{H = H_1} \quad (kN/m)$$

Post.

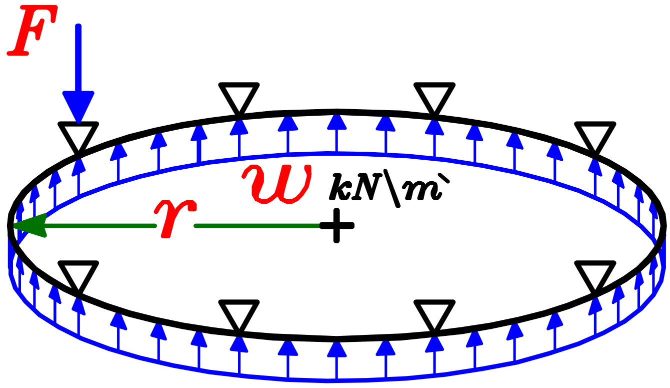
$$R = \frac{w * 2\pi r}{n}$$

n = No. of Posts

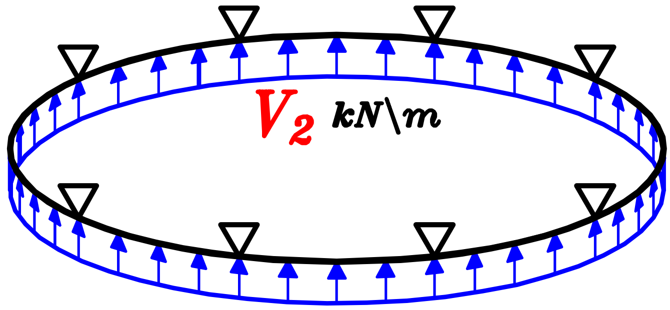
$$F = R + o.w._{(Post)}$$



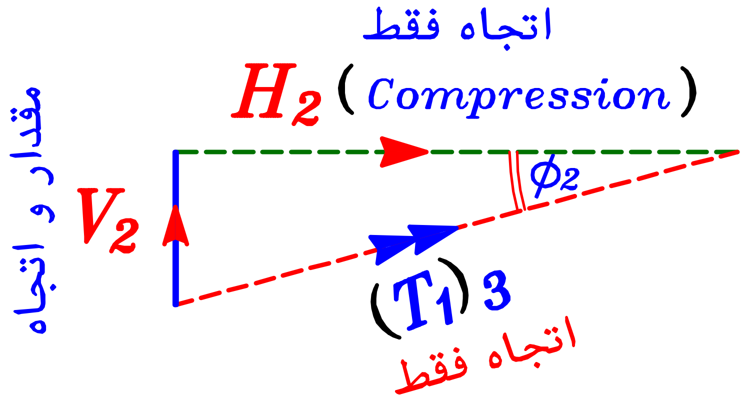
B_2



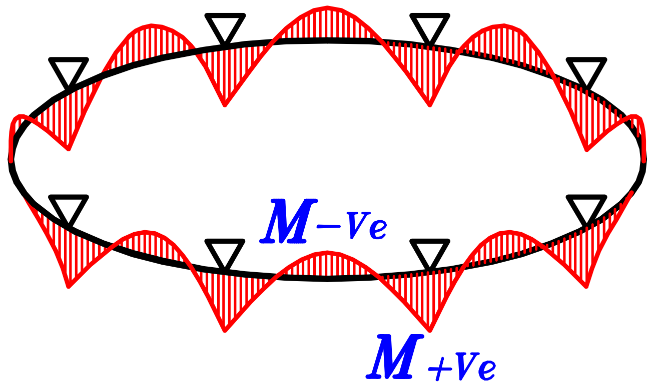
$$w = \frac{\sum weight}{Span} = \frac{\sum F}{2\pi r} \quad kN\backslash m$$



$$V_2 = w\uparrow - o.w.(Beam)\downarrow$$



$$P = H_2 * r$$

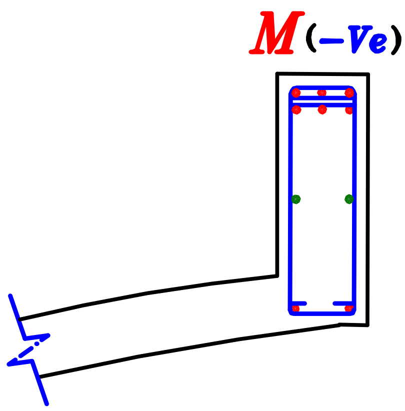


سيظل **max. Shear Force** & **max. Torsional Moment** كما هم .

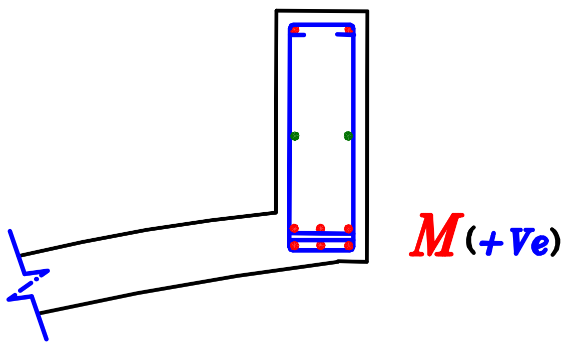
لكن اتجاه و قيمه كلا من ($max.\ M_{-Ve}$) و ($max.\ M_{+Ve}$) سينعكس

و ستكون قيمته فى الجدول من هى قيمه العزم الاخر .

Design the Beam on (M, P) & (Q, M_t)

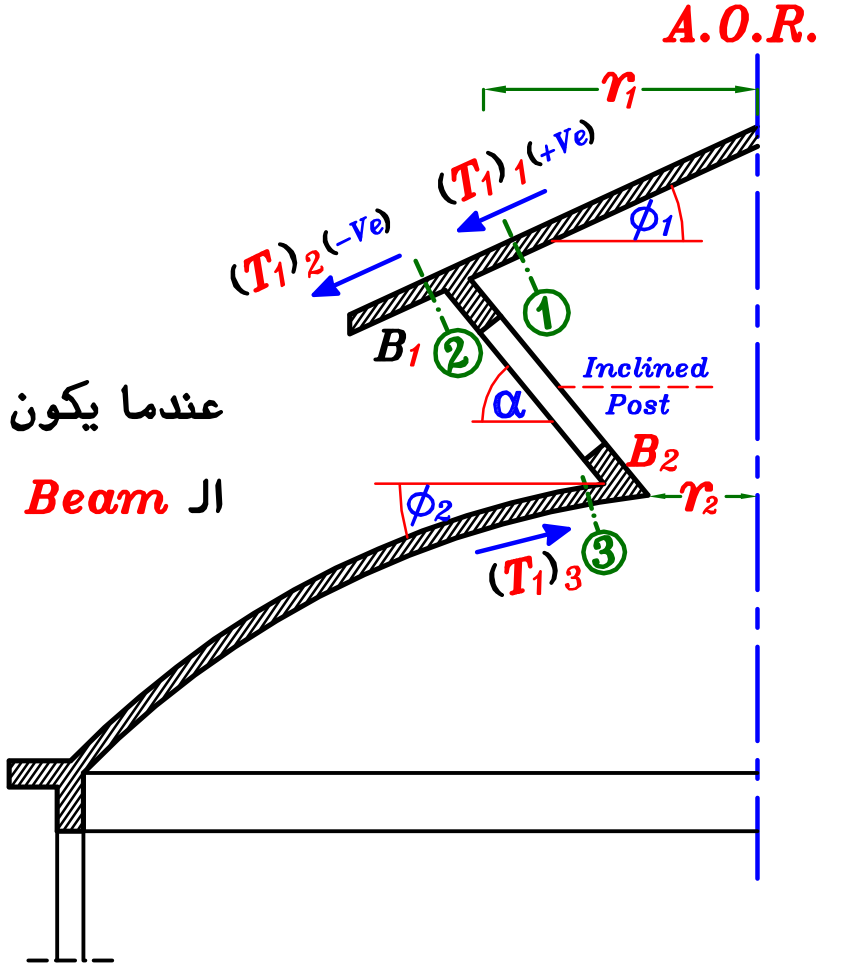


Sec. at mid Span



Sec. at Support

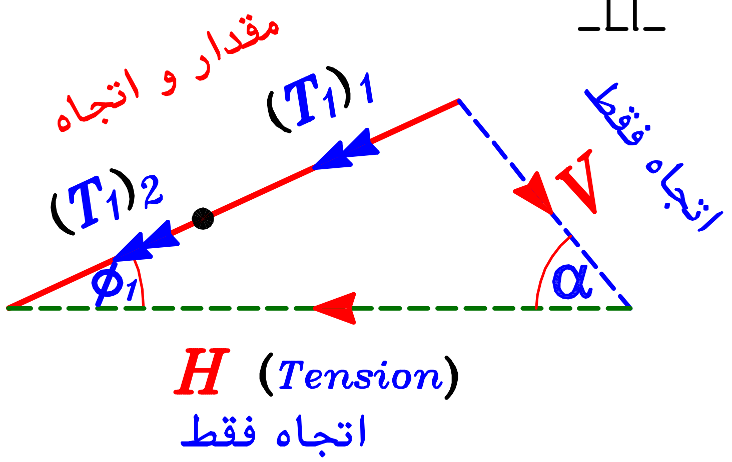
Example.

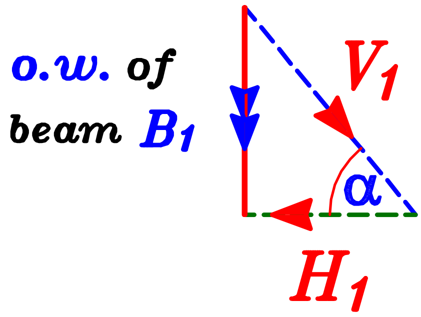


عندما يكون ال **Post** مائل يجب أن تكون

ال **Ring Beam** مائله بنفس ميل ال **Post**

B_1

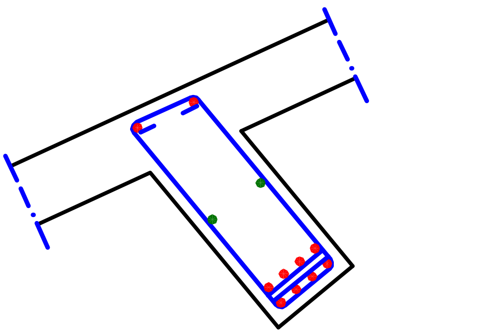




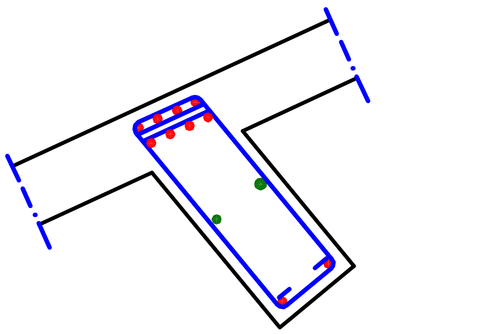
$$\boxed{V_{1\ total} = V + V_1}$$

$$\boxed{H_{1\ total} = H + H_1}$$

Design the Beam on (M, T) & (Q, M_t)



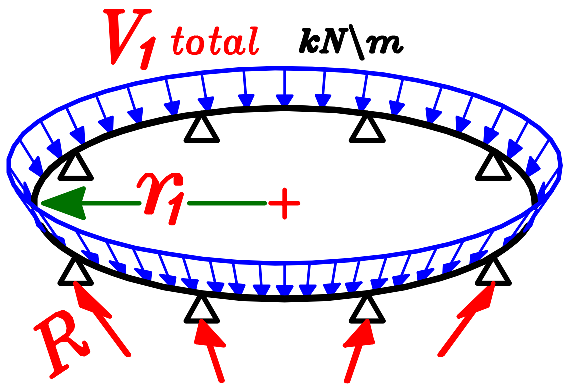
Sec. at mid Span

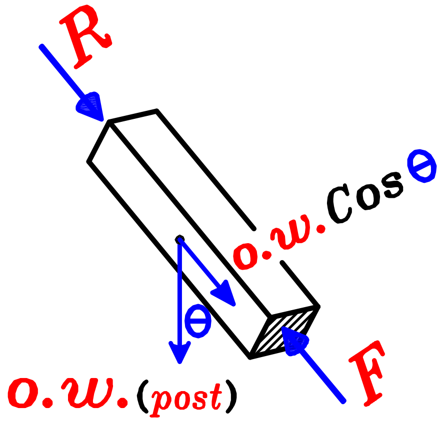


Sec. at Support

Post.

B_1



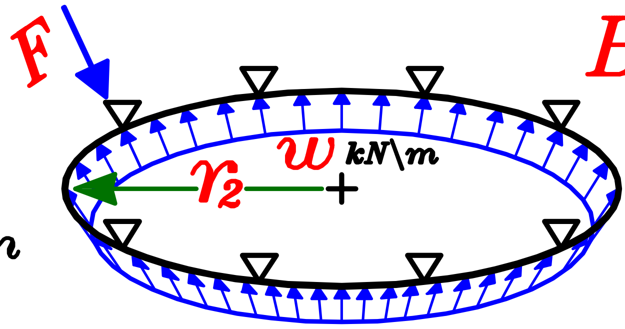


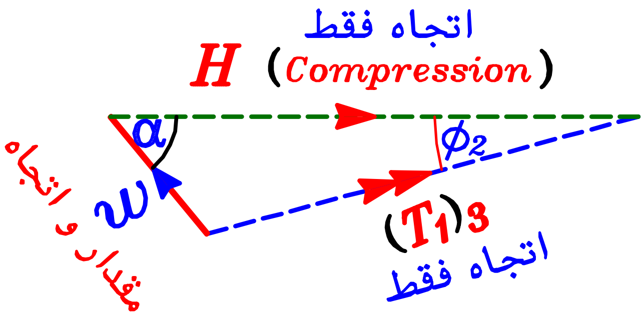
$$R = \frac{V_{1\,total} * 2\pi r_1}{n}$$

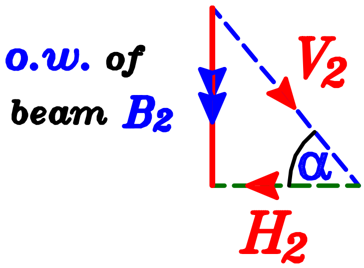
$$F = R + o.w._{(post)} * \cos\theta$$

B_2

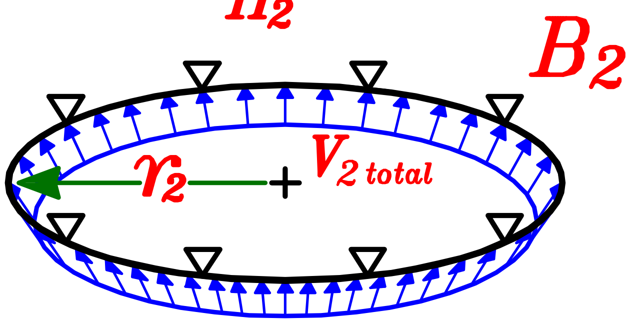
$$\boxed{w = \frac{\Sigma\, weight}{Span} = \frac{\Sigma F}{2\pi r_2}}$$ kN\m





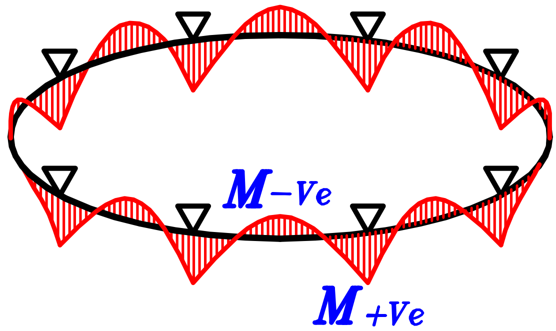


$$\boxed{V_{2\,total} = w - V_2}$$



$$\boxed{H_{2\,total} = H - H_2}$$ Comp.

$$\boxed{P = H_{2\,total} * r_2}$$



Design the Beam on (M, P)

& (Q, M_t)

2- Case of surface supported on another surface.

عندما يكون هناك سطح محمول مباشره على السطح الاخر

اى لا يوجد عند نقطه تقاطعهما كمره تحمل السطحين .

عندما يرتكز سطح دورانى على سطح أخر فانه نتيجه لاختلاف اتجاه (T_1) للسطح العلوى عن اتجاه (T_1) للسطح السفلى عند نقطه الارتكاز تتكون قوه افقيه عند نقطه الاتصال .

لمعرفه مقدار و اتجاه هذه القوه الافقيه

نقوم بتحليل القوه (T_1) للسطح المحمول الى مركبتين احداهما فى اتجاه السطح الحامل و الاخرى فى الاتجاه الافقى .

ثم نحسب المركبه الافقيه (H) و نحدد اذا ما كانت ***Tension or Compression***

لمقاومه هذه القوه الافقيه يتم عمل كمره افقيه ***(HL. beam)*** عند نقطه اتصال السطحين بعرض $(3\,t_s)$ من كل اتجاه أى ان مساحتها $\left(A_c = 3\,t_{s1} * t_{s1} + 3\,t_{s2} * t_{s2}\right)$

ثم نحدد قيمه ال ***Normal Force*** المؤثر على قطاع هذه الكمره .

$$\boxed{\text{Normal Force} = H * r}$$

و يتم تحديد كميه الحديد فى هذه الكمره بناء على نوع القوه الافقيه :

اذا كان ***Compression Force*** يتم تصميمه مثل ال ***Short Column***

$$P_{U.L.} = H * r * 1.5 = 0.35\,A_c\,F_{cu} + 0.67\,A_s\,F_y \xrightarrow{Get} A_s$$

$$\text{Check } A_{s_{min.}} = \frac{0.80}{100} * A_c$$

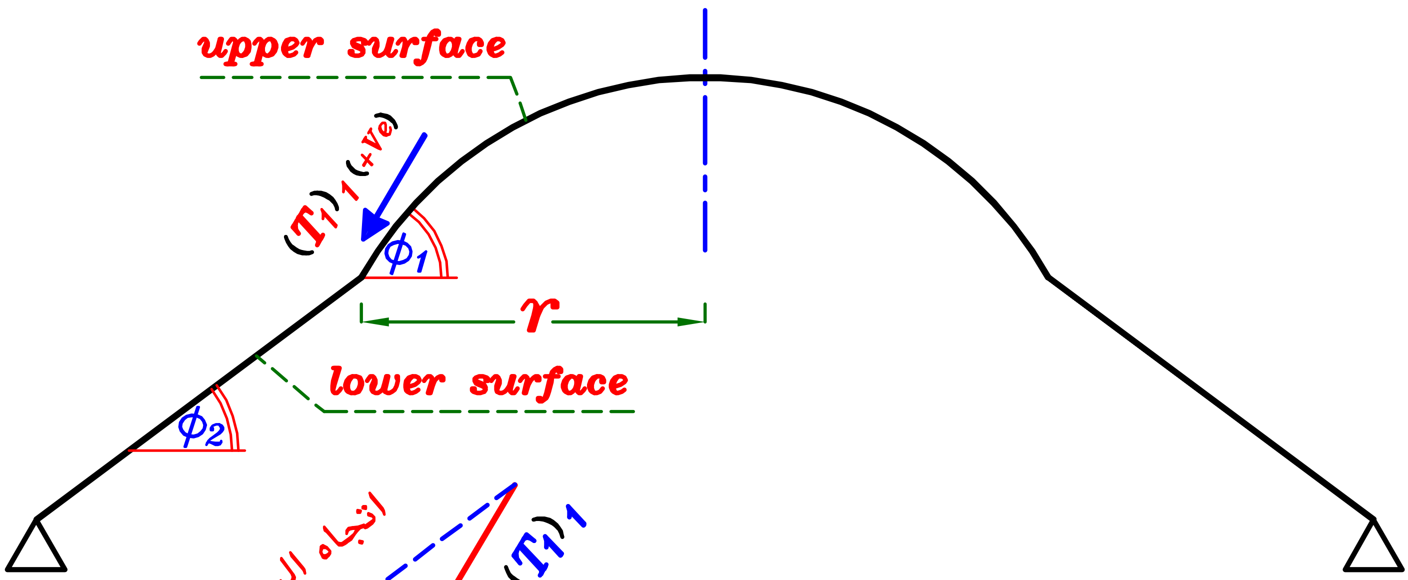
نضع كانات داخليه لزياده ال ***Confiment*** للخرسانه

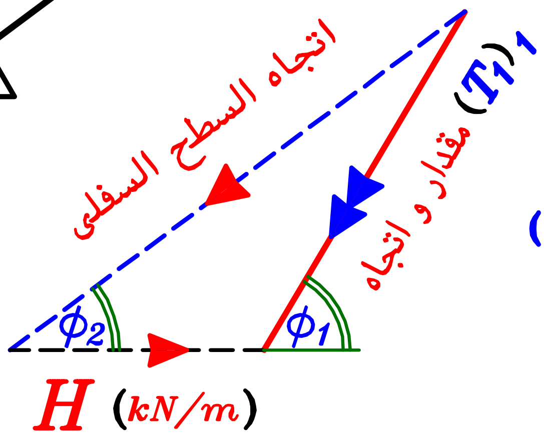
اذا كان ***Tension Force*** يتم تصميمه مثل ال ***Tie***

لا نحتاج لوضع كانات داخليه

$$\boxed{A_s = \frac{H * r * 1.5}{F_y / \delta_s}}$$

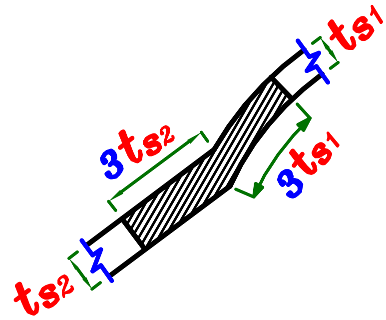
Example.





Compression اتجاهها للداخل

نقوم بتحليل القوه (T_1) للسطح العلوى (المحمول)
الى مركبتين احداهما فى اتجاه السطح السفلى (الحامل)
و الاخرى فى الاتجاه الافقى .
ثم نحسب المركبه الافقيه (H)
و نحدد اذا ما كانت Tension or Compression



Compression Force $= H * r$

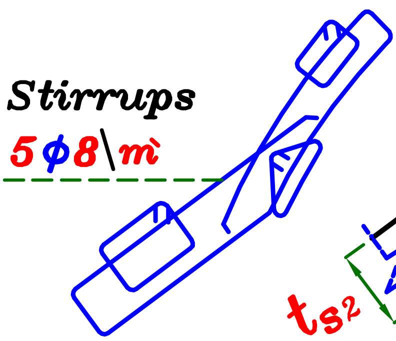
Design the HL. Beam as a short Column

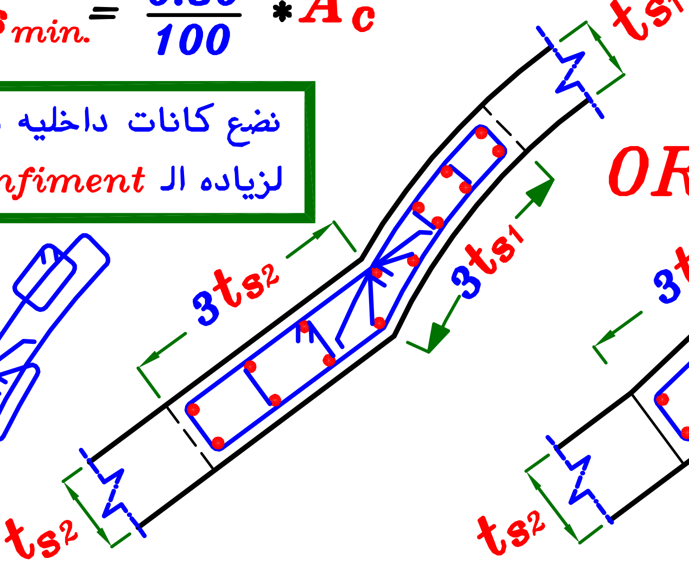
$$A_c = 3t_{s1} * t_{s1} + 3t_{s2} * t_{s2} = 3t_{s1}^2 + 3t_{s2}^2$$

$$P_{U.L.} = H * r * 1.5 = 0.35\, A_c\, F_{cu} + 0.67\, A_s\, F_y \xrightarrow{Get} A_s$$

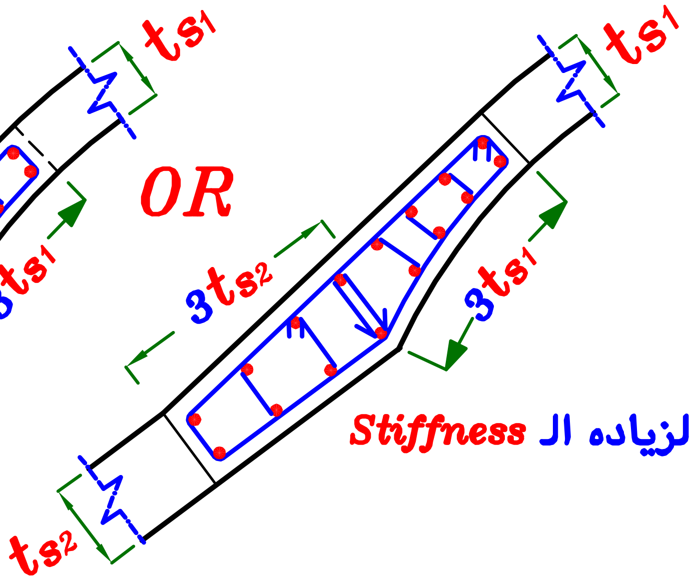
Check $A_{s_{min.}} = \frac{0.80}{100} * A_c$

نضع كانات داخليه مثل الاعمده
لزياده ال Confiment للخرسانه



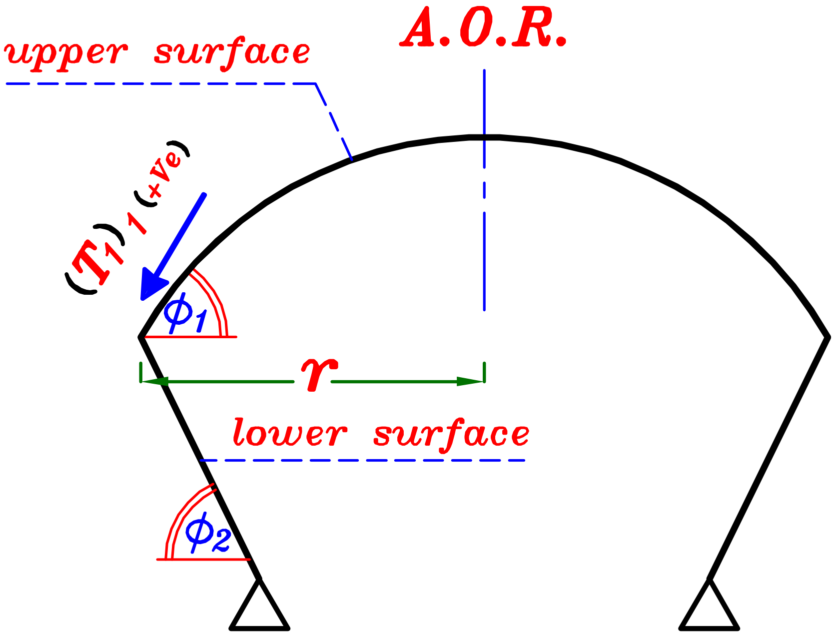


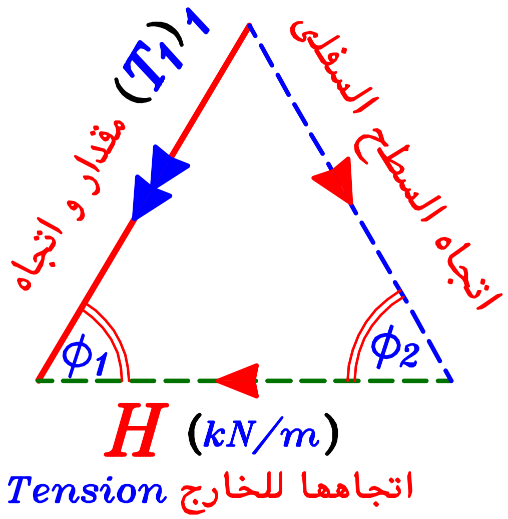
OR



لزياده ال Stiffness

Example.





نقوم بتحليل القوه (T_1) للسطح العلوى (المحمول)

الى مركبتين احداهما فى اتجاه السطح السفلى (الحامل)

و الاخرى فى الاتجاه الافقى .

ثم نحسب المركبه الافقيه (H)

و نحدد اذا ما كانت Tension or Compression

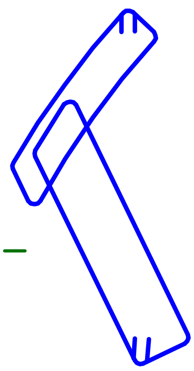
Tension Force $= H * r$

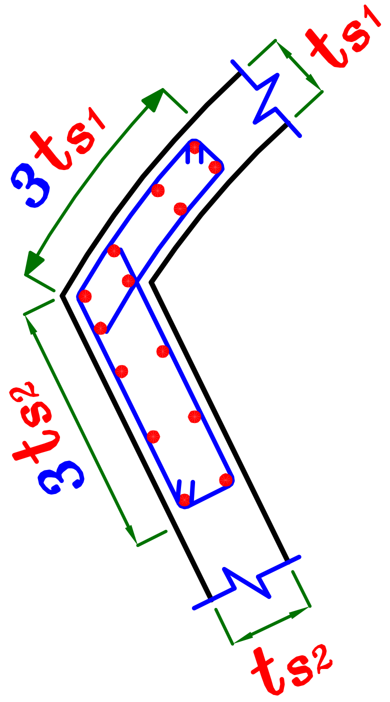
Design the HL. Beam as a Tie.

$$\boxed{A_s = \frac{H * r * 1.5}{F_y / \gamma_s}}$$

Stirrups

$5\phi 8 \backslash m'$

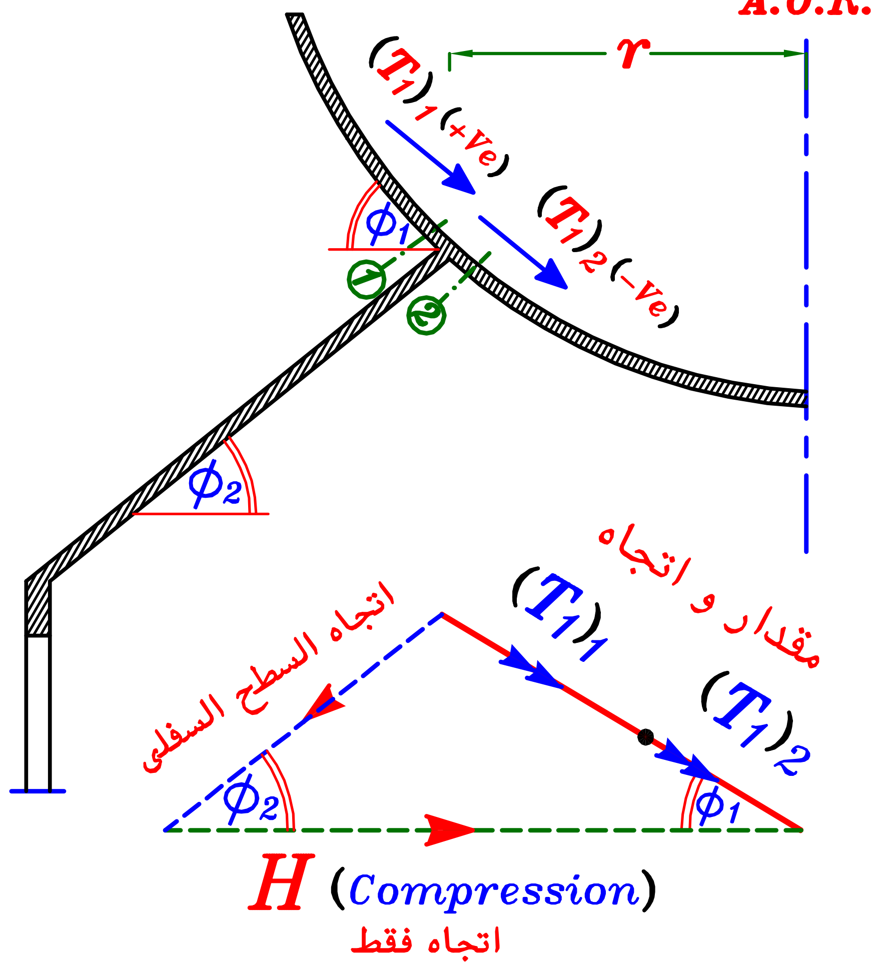




لا نحتاج لكانات داخليه

Example.

B_1



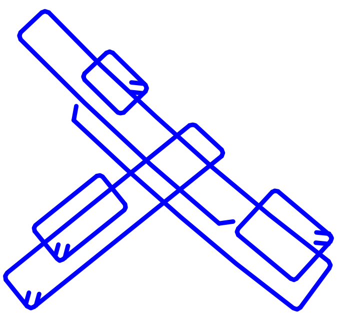
$$\text{Compression Force} = H * r$$

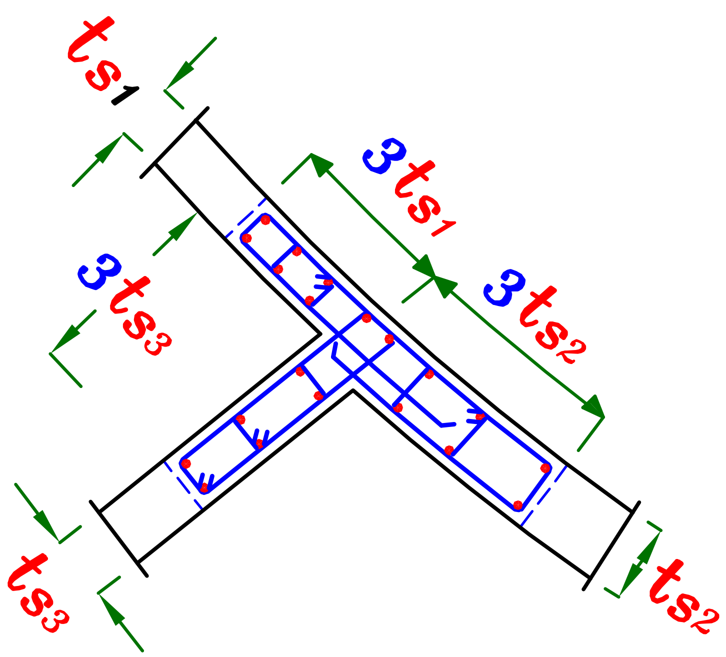
Design the HL. Beam as short Column

$$P_{U.L.} = H * r * 1.5 = 0.35\, A_c\, F_{cu} + 0.67\, A_s\, F_y \xrightarrow{Get} A_s$$

$$A_c = 3\, t_{s_1}^2 + 3\, t_{s_2}^2 + 3\, t_{s_3}^2$$

Stirrups
$5\phi 8 \backslash m'$



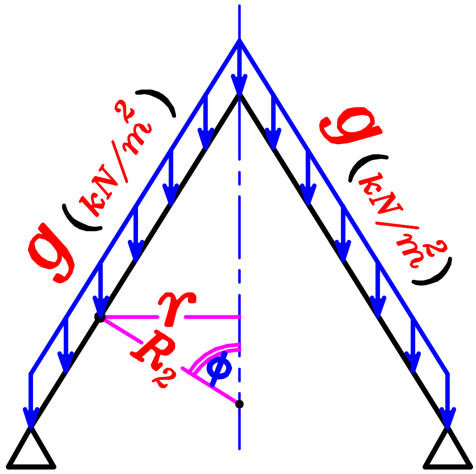


نضع كانات داخليه مثل الاعمده
لزياده ال Confiment للخرسانه

اثبات نظرى

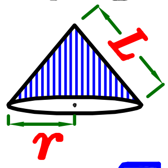
Derive an equation to get T_1 & T_2 At the vertex point in Cones.

In domes $R_1 = \infty$



For T_1 at any point.

$S.A. = \pi * r * L$



$L = \dfrac{r}{\cos\phi}$ $\quad \therefore S.A. = \dfrac{\pi * r^2}{\cos\phi}$

$W_\phi = g * S.A. = g * \dfrac{\pi * r^2}{\cos\phi}$

$\therefore T_1 = \dfrac{W_\phi}{2\pi r \sin\phi} = \dfrac{g * \cancel{\pi} * r^{\cancel{2}}}{2\cancel{\pi}\cancel{r} \sin\phi \cos\phi} = \dfrac{g * r}{2 \sin\phi \cos\phi}$

$$\therefore \boxed{T_1 = \frac{g * r}{2 \sin\phi \cos\phi}}$$

For T_2 at any point.

$Z = g * \cos\phi \quad , \quad R_2 = \dfrac{r}{\sin\phi}$

In Cones $R_1 = \infty \rightarrow \dfrac{T_1}{R_1} = Zero \rightarrow \dfrac{T_2}{R_2} = Z$

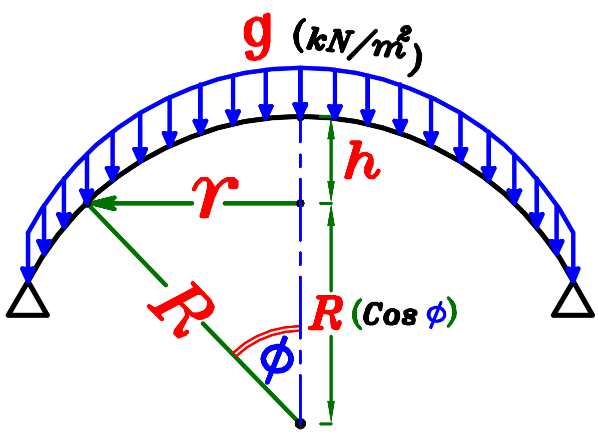
$\therefore T_2 = R_2 * Z = \dfrac{r}{\sin\phi} * g \cos\phi = \dfrac{g * r}{\tan\phi} \quad \therefore \boxed{T_2 = \dfrac{g * r}{\tan\phi}}$

At the Vertex of the Cone $r = Zero$

$\therefore \boxed{T_1 = T_2 = Zero}$ حفظ

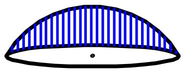
Derive an equation to get T_1 & T_2 At the vertex point in Domes.

In domes $R_1 = R_2 = R$



With dead Load.

$S.A. = 2\pi * R * h$



$W\phi = g * (2\pi * R * h)$

$h = R - R\,Cos\,\phi = R\,(1 - Cos\,\phi)$

$\because\ r = R\,Sin\,\phi$

For T_1 at any point.

$$\because\ T_1 = \frac{W\phi}{2\pi r\,Sin\phi} = \frac{g * 2\pi * R * h}{2\pi r\,Sin\phi} = \frac{g * \cancel{2}\cancel{\pi} * \cancel{R} * R\,(1 - Cos\,\phi)}{\cancel{2}\cancel{\pi} * \cancel{R}\,Sin\,\phi * Sin\,\phi}$$

$$\therefore\ T_1 = g\,R * \frac{(1 - Cos\,\phi)}{Sin^2\phi} \qquad \text{multiply by } \frac{(1 + Cos\,\phi)}{(1 + Cos\,\phi)}$$

$$\therefore\ T_1 = g\,R * \frac{(1 - Cos\,\phi)}{Sin^2\phi} * \frac{(1 + Cos\,\phi)}{(1 + Cos\,\phi)}$$

$$\because\ (1 - Cos\,\phi)(1 + Cos\,\phi) = Sin^2\phi$$

$$\therefore\ T_1 = g\,R * \frac{\cancel{Sin^2\phi}}{\cancel{Sin^2\phi}\,(1 + Cos\,\phi)} = \frac{g * R}{(1 + Cos\,\phi)}$$

$$\because\ Z = g\,Cos\,\phi \qquad \therefore\ g = \frac{Z}{Cos\,\phi}$$

$$\therefore\ \boxed{T_1 = \frac{Z * R}{Cos\,\phi\,(1 + Cos\,\phi)}}$$

For T_2 at any point.

$\because \frac{T_1}{R_1} + \frac{T_2}{R_2} = Z$ $\quad\because$ In Domes $R_1 = R_2 = R$

$\therefore \frac{T_1 + T_2}{R} = Z$ $\quad\therefore T_1 + T_2 = Z * R$

$\therefore T_2 = Z * R - T_1$ $\quad\because T_1 = \frac{Z * R}{\cos\phi\,(1 + \cos\phi)}$

$$\therefore T_2 = Z * R - \frac{Z * R}{\cos\phi\,(1 + \cos\phi)} = Z * R \left(1 - \frac{1}{\cos\phi\,(1 + \cos\phi)}\right)$$

$$\therefore \boxed{T_2 = Z * R \left(1 - \frac{1}{\cos\phi\,(1 + \cos\phi)}\right)}$$

At the Vertex of the Dome $\phi = \text{Zero}$

$$T_1 = \frac{Z * R}{\cos\phi\,(1 + \cos\phi)} = \frac{Z * R}{\cos 0\,(1 + \cos 0)} = \frac{Z * R}{2}$$

$$T_2 = Z * R \left(1 - \frac{1}{\cos\phi\,(1 + \cos\phi)}\right) = Z * R \left(1 - \frac{1}{\cos 0\,(1 + \cos 0)}\right)$$

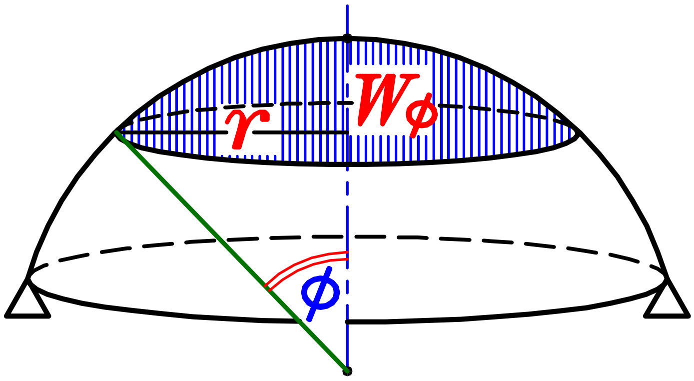
$$T_2 = \frac{Z * R}{2}$$

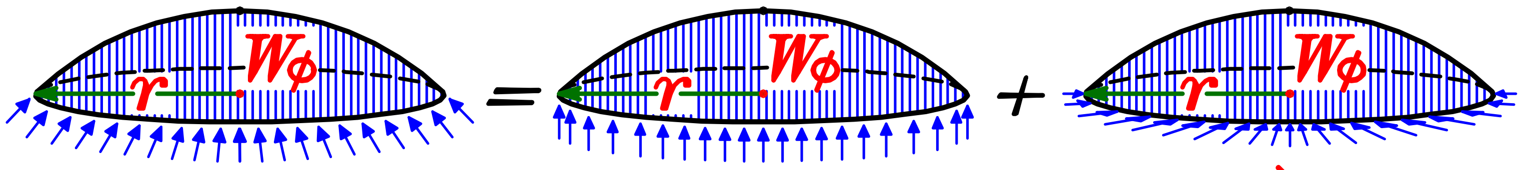
$\therefore$ At vertex of the Dome $\quad \boxed{T_1 = T_2 = \frac{RZ}{2}}$

حفظ

Prove That at any Point at S.O.R. اثبات نظرى

$$\boxed{T_1 = \frac{W_\phi}{2\pi r \ Sin\phi}}$$



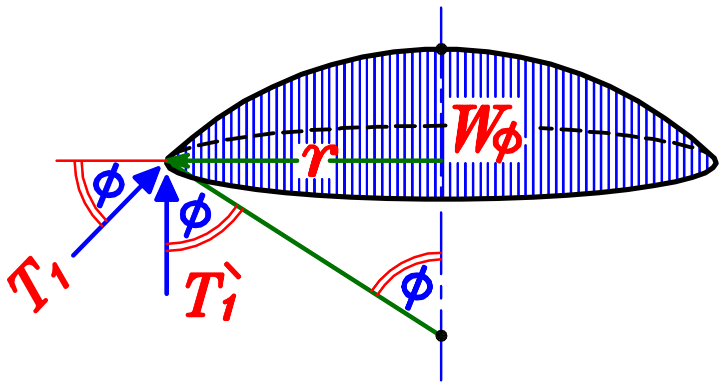


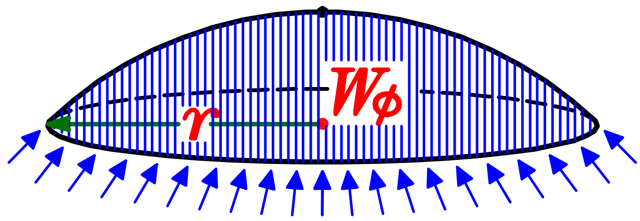
T_1 (kN/m) $\qquad$ T_1' (kN/m) $\qquad$ T_1'' (kN/m)

المركبه الرأسيه ل T_1 $\qquad$ المركبه الافقيه ل T_1

$T_1' = T_1 * Sin\phi$ $\qquad$ $T_1'' = T_1 * Cos\phi$

$$\because T_1' = \frac{Weight}{Perimeter} = \frac{W_\phi}{2\pi r} = \checkmark \ (kN/m)$$





T_1 (kN/m)

$$\because T_1' = T_1 * Sin\phi \longrightarrow \therefore T_1 * Sin\phi = \frac{W_\phi}{2\pi r}$$

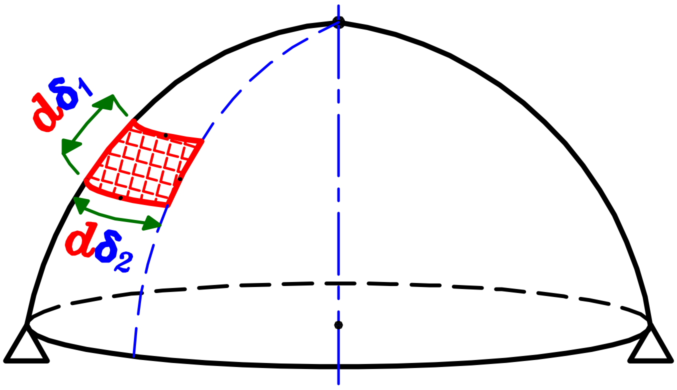
$$\therefore \boxed{T_1 = \frac{W_\phi}{2\pi r \ Sin\phi}}$$

Prove That at any Point at S.O.R.

اثبات نظرى

$$\boxed{\frac{T_1}{R_1} + \frac{T_2}{R_2} = Z}$$

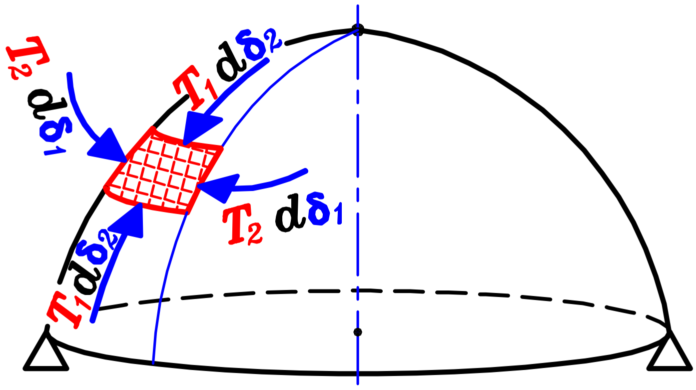
بدراسه مساحه صغيره من السطح تساوى $(d\delta_1 * d\delta_2)$



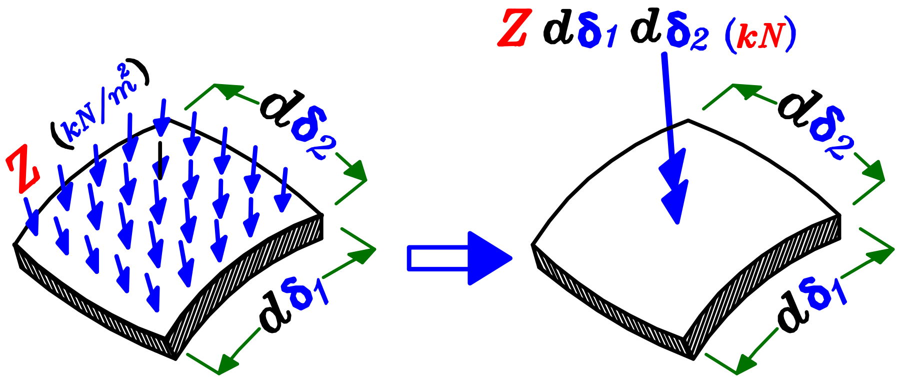
ستكون القوى المؤثره على هذه المساحه

تساوى $(T_1\,(kN/m) * d\delta_2)$ فى اتجاه ال **Meridian direction**

و تساوى $(T_2\,(kN/m) * d\delta_1)$ فى اتجاه ال **Ring direction**



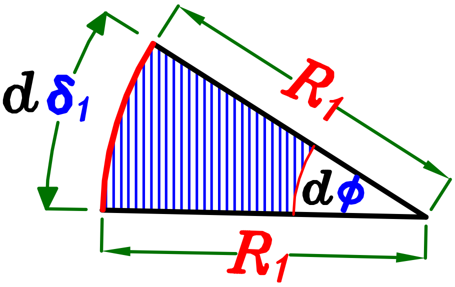
(Z) هى محصله القوى الخارجيه العموديه على السطح فى المتر المربع من السطح .



$\boxed{Z * d\delta_1 * d\delta_2}$

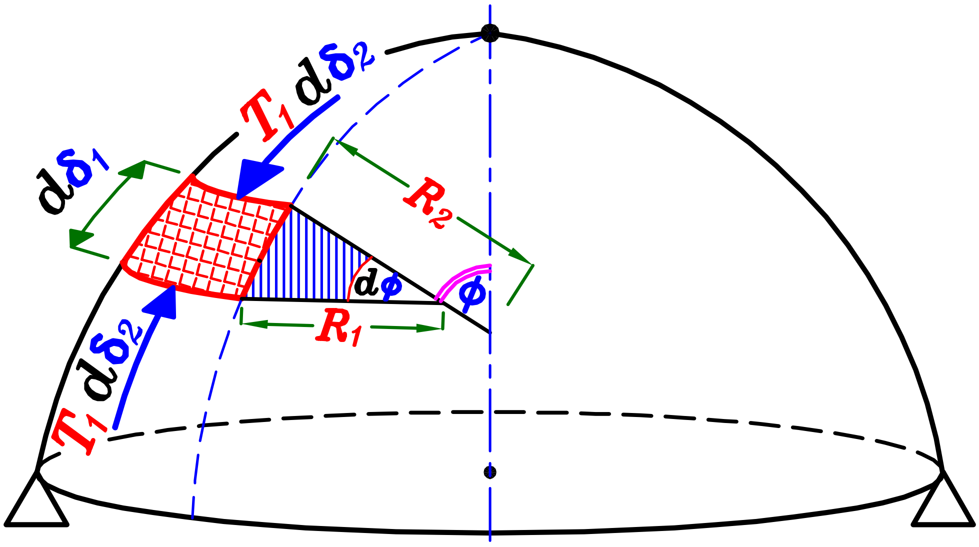
هى محصله القوى الخارجيه العموديه على السطح لمساحه $(d\delta_1 * d\delta_2)$ من السطح

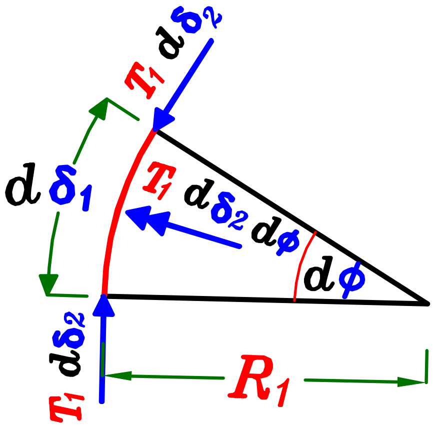
المستوى الرأسى



$$\boxed{d\,\delta_1 = R_1 * d\,\phi}$$

Elevation

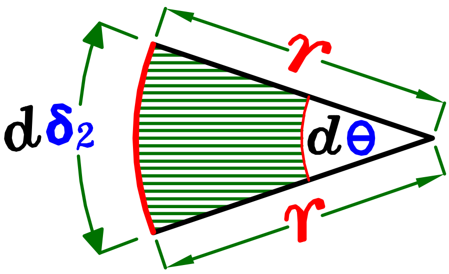




$$\boxed{T_1 * d\,\delta_2 * d\,\phi}$$

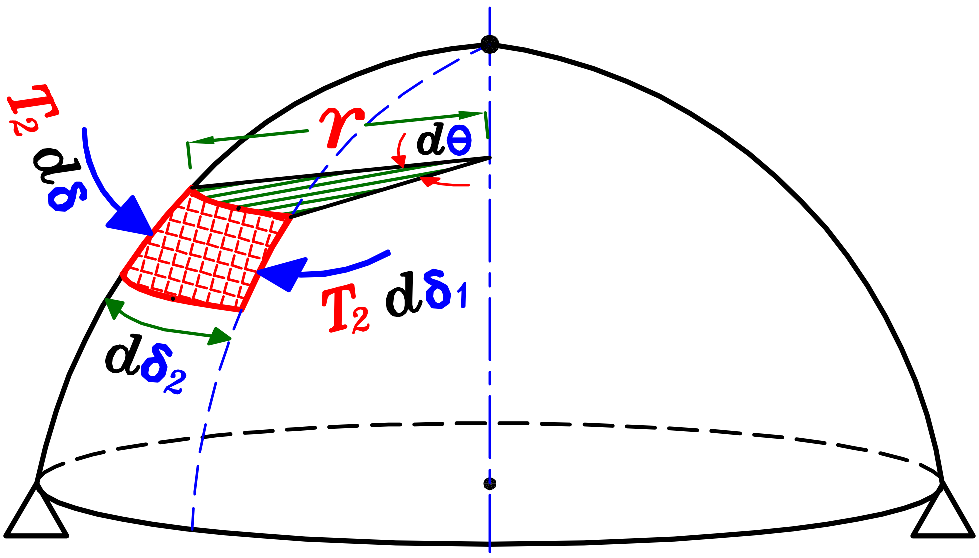
هى مركبه القوى الداخليه T_1
العموديه على السطح و المؤثره
على مساحه $(d\delta_1 * d\delta_2)$ من السطح

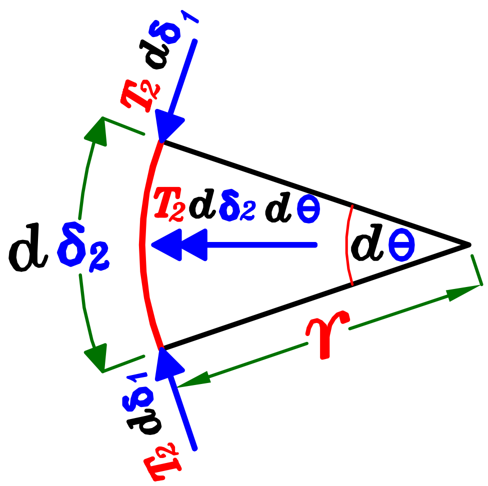
المستوى الافقى



$$\boxed{d\,\delta_2 = r * d\,\theta}$$

Plan

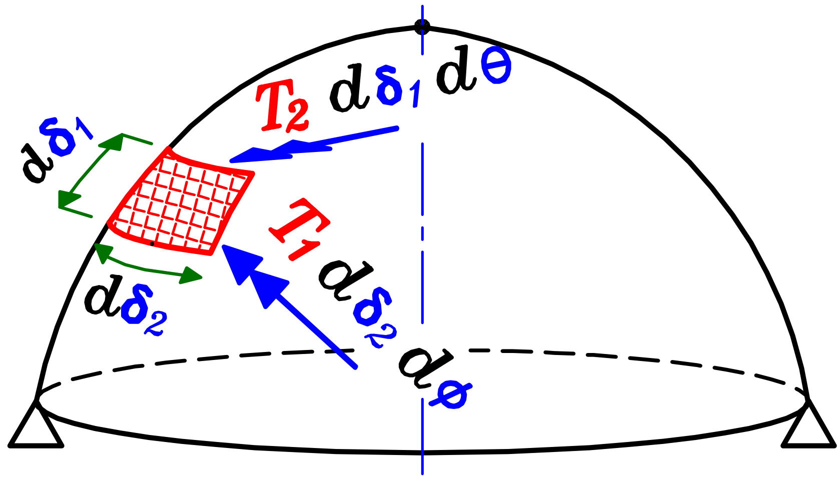




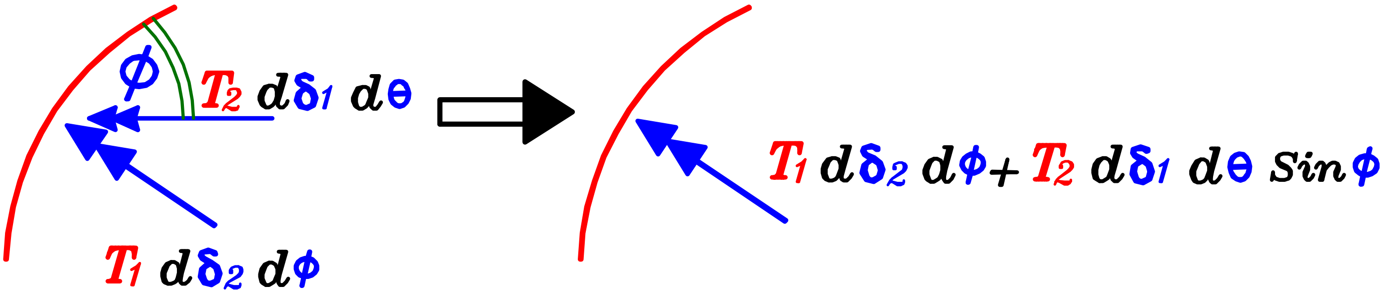
$$\boxed{T_2 * d\,\delta_1 * d\,\theta}$$

هى مركبه القوى الداخليه T_2 الافقيه
و المؤثره على مساحه $(d\delta_1 * d\delta_2)$
من السطح

لتحديد محصله مركبات القوى الداخليه العموديه على السطح

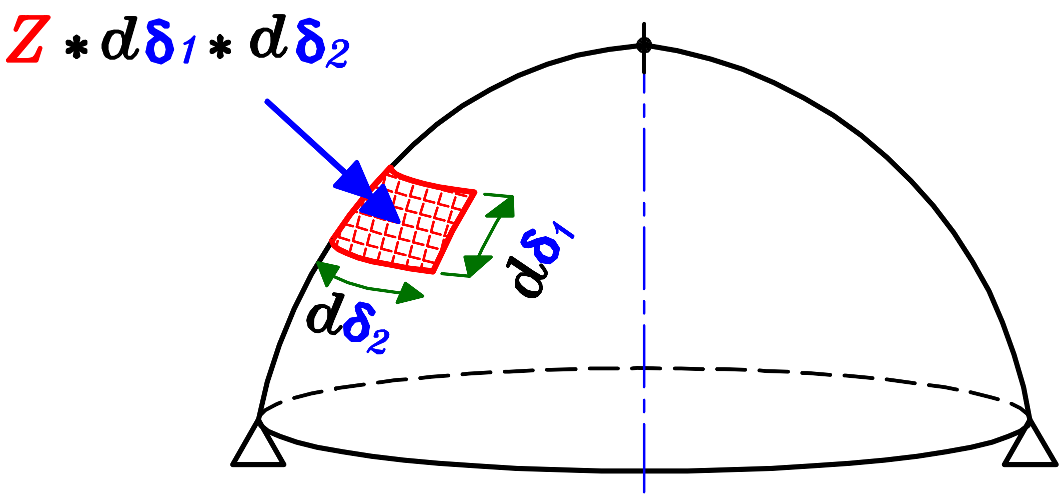


Elevation



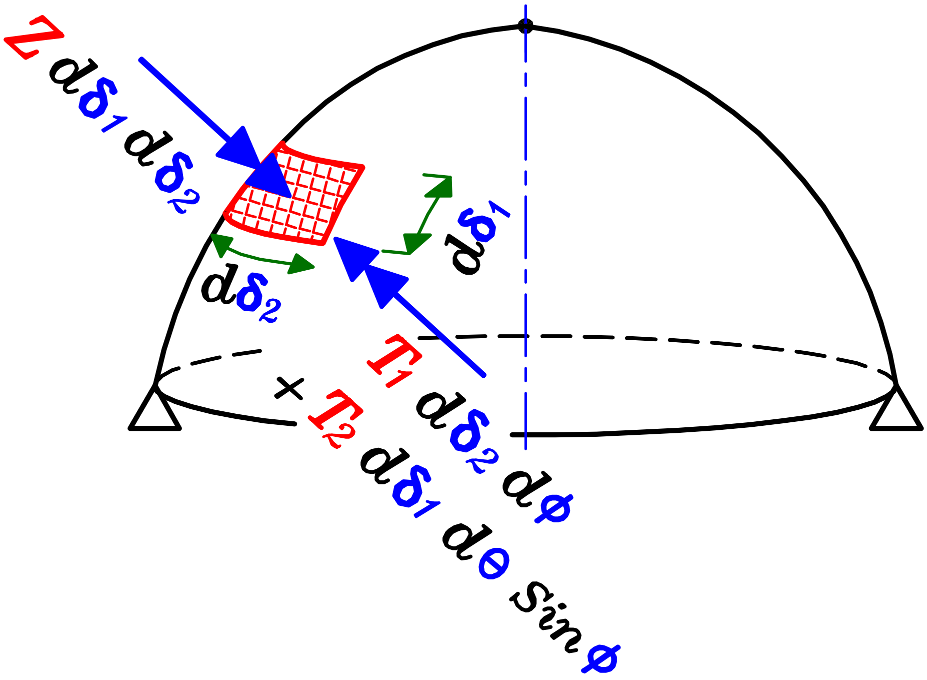
∴ محصله مركبات القوى الداخليه العموديه على السطح لمساحه $(d\delta_1 * d\delta_2)$

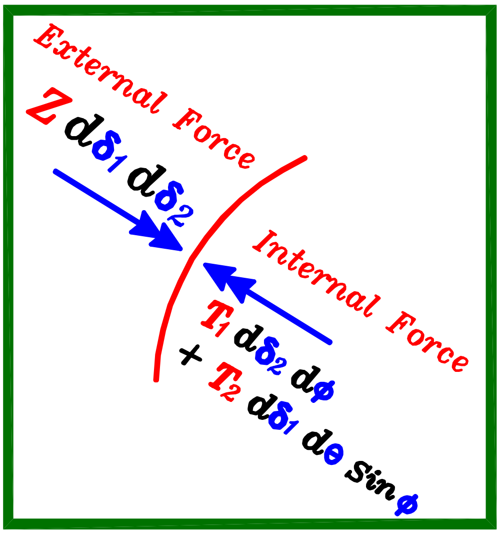
$$= \boxed{T_1\ d\delta_2\ d\phi + T_2\ d\delta_1\ d\theta\ Sin\phi}$$



محصله القوى الخارجيه العموديه على السطح لمساحه $(d\delta_1 * d\delta_2)$

$$= \boxed{Z * d\delta_1 * d\delta_2}$$





$\because$ *External Force = Internal Force*

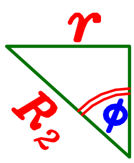
$$\therefore\; Z * d\delta_1 * d\delta_2 = T_1 * d\delta_2 * d\phi + T_2 * d\delta_1 * d\theta * Sin\phi$$

$$\because\; d\delta_1 = R_1 * d\phi \quad , \quad d\delta_2 = r * d\theta$$

$$\therefore\; Z * R_1 * \cancel{d\phi} * r * \cancel{d\theta} = T_1 * r * \cancel{d\theta} * \cancel{d\phi} + T_2 * R_1 * \cancel{d\phi} * \cancel{d\theta} * Sin\,\phi$$

$$\therefore\; Z * R_1 * r = T_1 * r + T_2 * R_1 * Sin\,\phi$$

$$\because\; r = R_2 * Sin\,\phi$$



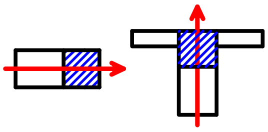
$$\therefore\; Z * R_1 * R_2 * \cancel{Sin}\,\phi = T_1 * R_2 * \cancel{Sin}\phi + T_2 * R_1 * \cancel{Sin}\,\phi$$

divided by $R_1 * R_2$

$$\frac{Z * R_1 * R_2}{R_1 * R_2} = \frac{T_1 * R_2}{R_1 * R_2} + \frac{T_2 * R_1}{R_1 * R_2}$$

$$\therefore\; \boxed{\frac{T_1}{R_1} + \frac{T_2}{R_2} = Z}$$

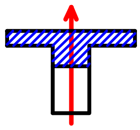
Design M , P Revision.



فى حاله وجود M , P يجب عمل تصميم للقطاع على أنه R–Sec.

أما فى حاله وجود M فقط فيجب مراعاه إذا ما كان القطاع

R–Sec. or T–Sec. or L–Sec.



Check: IF P neglected or not.

1– IF $K = \frac{P_{U.L.}}{F_{cu}\, b\, t} \leqslant 0.04 \longrightarrow$ neglect $P_{U.L.}$

2 – IF $K = \frac{P_{U.L.}}{F_{cu}\, b\, t} > 0.04$ Design the Sec. on both N.F.&B.M.

Get Reinforcement A_s , A_s`

Get $e = \frac{M_{U.L.}}{P_{U.L.}}$ Get $\frac{e}{t}$

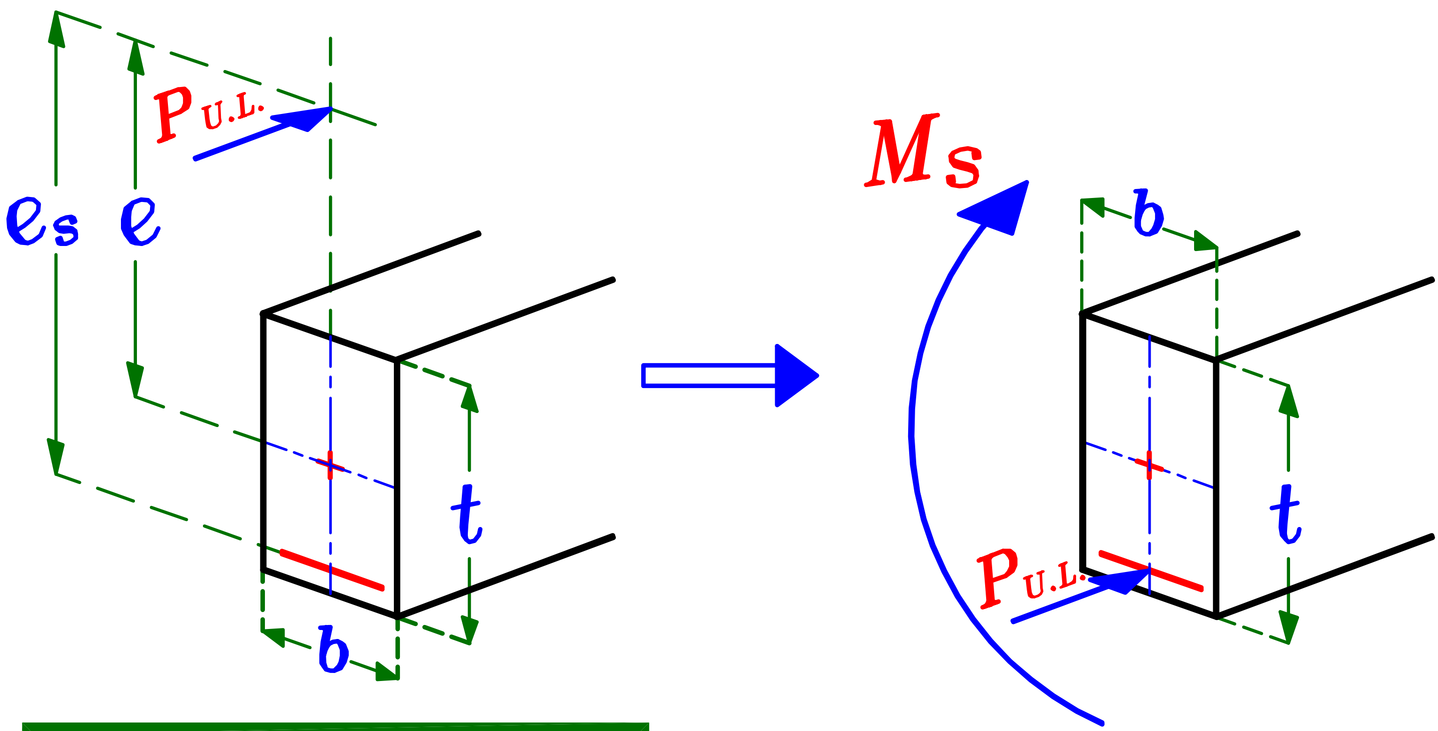
t هو العرض الموازى لل moment

– IF $\boxed{\frac{e}{t}}$

$\frac{e}{t} \geqslant 0.5$ → Use e_s

$\frac{e}{t} < 0.5$ → Use I.D.

① $\frac{e}{t} \geqslant 0.5$ Big Eccentricity.



$$\boxed{e_s = e + \frac{t}{2} - c}$$

$$\boxed{M_s = P_{U.L.} * e_s}$$

$$\boxed{d = c_1 \sqrt{\frac{M_s}{F_{cu}\, b}}}$$

Get $C_1 = \checkmark \xrightarrow{get} J = \checkmark$

$$\boxed{A_s = \frac{M_s}{J\, F_y\, d} - \frac{P_{U.L.}}{(F_y/\gamma_s)}}$$

– Check $A_{s_{min.}} = \left(0.225 * \frac{\sqrt{F_{cu}}}{F_y}\right) b\, d$ as beams

② $\frac{e}{t} < 0.5$ Small Eccentricity.

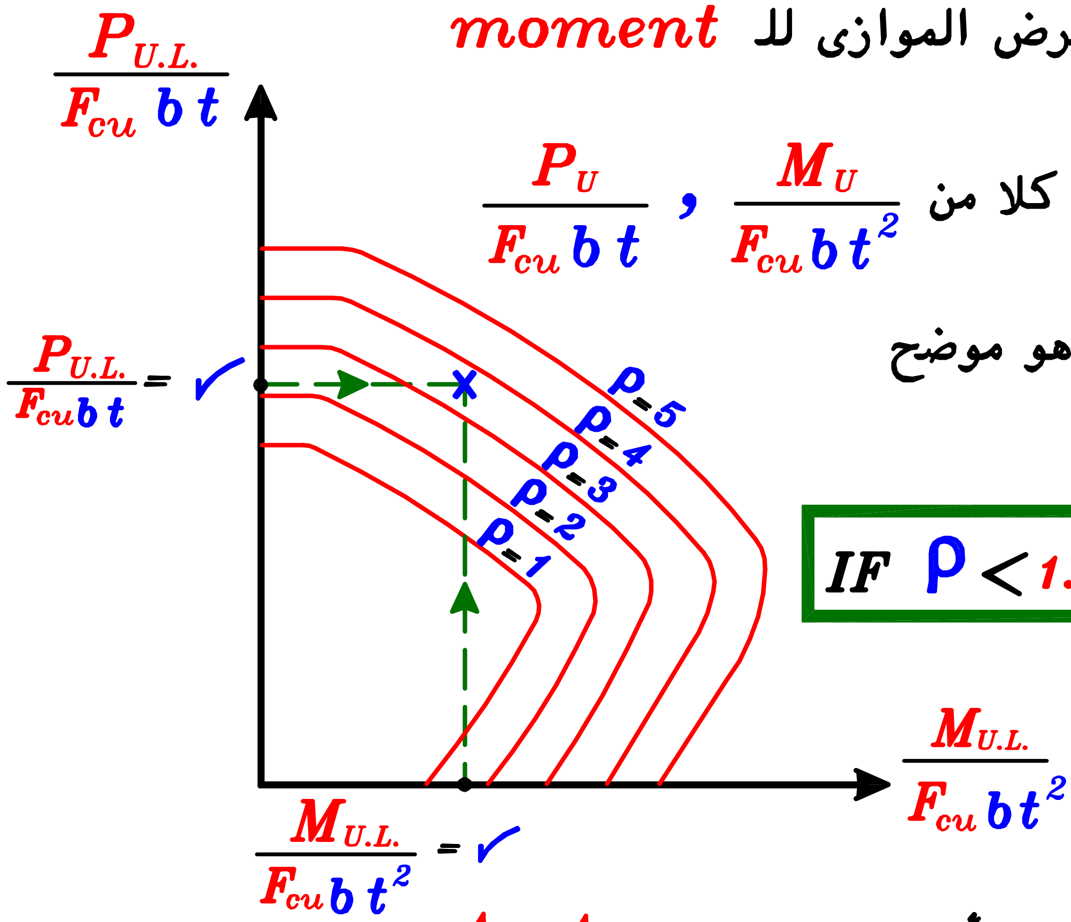
To get A_s, $A_{s'}$ use Interaction Diagram.

Use I.D. $\boxed{\text{ECCS Pages } (4-20) \longrightarrow (4-63)}$

بعد تحديد ال *Curve* بمعرفة كل من F_y, ζ, α

نحدد قيمه كل من $\frac{P_U}{F_{cu}\, b\, t}$, $\frac{M_U}{F_{cu}\, b\, t^2}$

حيث ال t هى العرض الموازى لل *moment*



بعد تحديد نقطه تقاطع كلا من $\frac{P_U}{F_{cu}\, b\, t}$, $\frac{M_U}{F_{cu}\, b\, t^2}$

نحدد قيمه ρ كما هو موضح

$\boxed{\text{IF } \rho < 1.0 \xrightarrow{\text{Take}} \rho = 1.0}$

ثم نعوض فى المعادلات الأتيه لتحديد قيمه A_s , $A_{s'}$

$$\boxed{\begin{aligned} \mu &= \rho * F_{cu} * 10^{-4} \\ A_s &= \mu * b * t \\ A_{s'} &= \alpha * A_s \end{aligned}}$$

Check $A_{s_{min.}} = \frac{0.8}{100} * b * t$

as columns

Design M, T Revision.

Get Reinforcement A_{s1}, A_{s2}

Get $e = \frac{M}{T}$ Then get $\frac{e}{t}$

IF $\boxed{\frac{e}{t}}$

$\frac{e}{t} \geqslant 0.5$ Big Eccentricity

$\frac{e}{t} < 0.5$ Small Eccentricity

① $\frac{e}{t} \geqslant 0.5$ Big Eccentricity.

$$\boxed{e_s = e - \frac{t}{2} + c}$$

$$\boxed{M_s = T_{U.L.} * e_s}$$

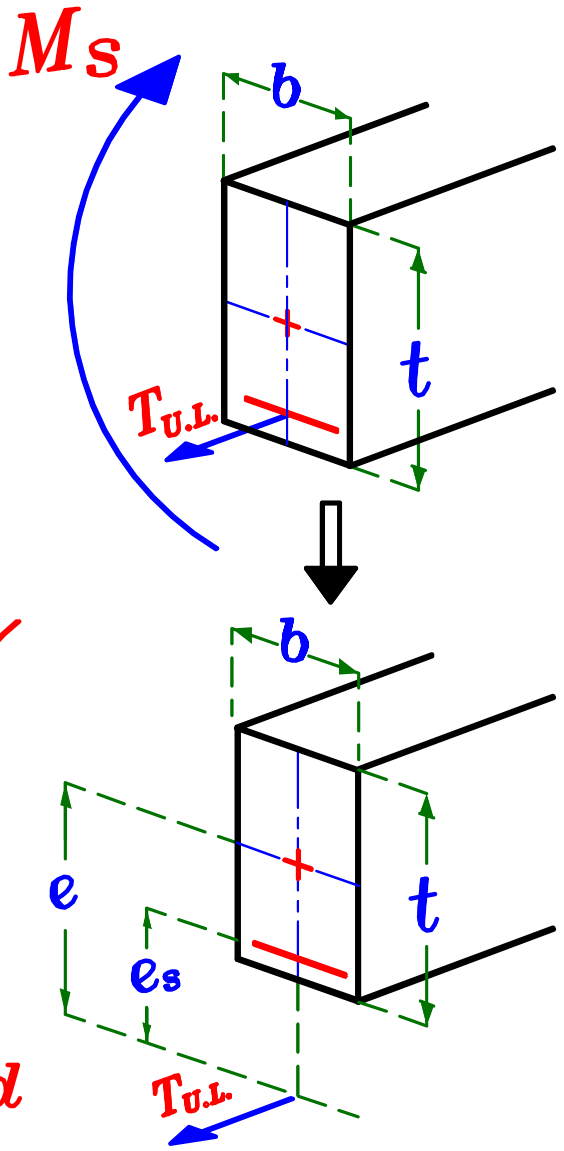
$$\boxed{d = c_1 \sqrt{\frac{M_s}{F_{cu}\, b}}}$$

Get $C_1 = \checkmark$

get $\longrightarrow J = \checkmark$

$$\boxed{A_s = \frac{M_s}{J\, F_y\, d} + \frac{T_{U.L.}}{(F_y/\gamma_s)}}$$

Check $A_{s_{min.}} = \left(0.225 * \frac{\sqrt{F_{cu}}}{F_y}\right) b\, d$



② $\frac{e}{t} < 0.5$ Small Eccentricity.

∴ محصله القوى العموديه تكون داخل القطاع.

القطاع أقرب لقطاع الـ *Tie* منه لقطاع الكمره .

أى أن الخرسانه عليها *Tension* من الجهتين .

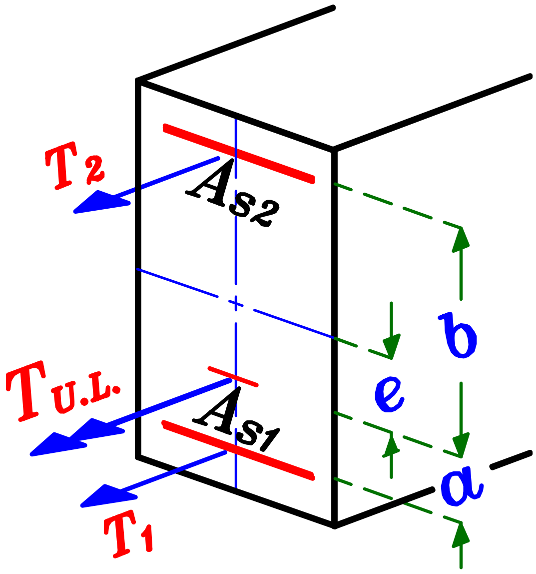
و تكون الخرسانه مشرخه من الجهتين و يقاوم الحديد كل الـ *Tension* .

$$\boxed{a = \frac{t}{2} - c - e}$$

a هى بعد المحصله عن الحديد الاقرب لها

$$\boxed{b = \frac{t}{2} - c + e}$$

b هى بعد المحصله عن الحديد الابعد عنها



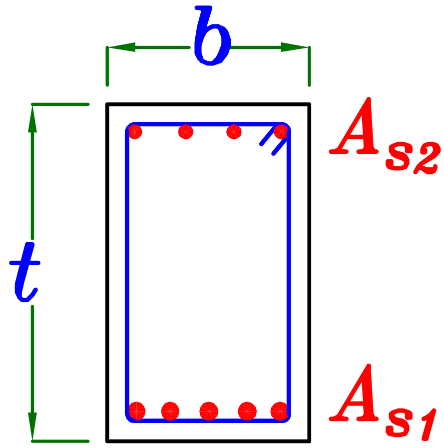
نحسب مركبتين الشد T_1 و T_2 عند الحديد القريب و البعيد عن المحصله

و منهم نحسب مساحه الحديد المطلوبه لحمل هذه القوى A_{s1} و A_{s2}

بأخذ العزم عند T_2

$$\because \; T_1\,(a+b) = T\,(b) \xrightarrow{Get} T_1$$

$$\because \; T = T_1 + T_2 \xrightarrow{Get} T_2$$



$$\boxed{A_{s1} = \frac{T_1}{(F_y/\gamma_s)}} \qquad \boxed{A_{s2} = \frac{T_2}{(F_y/\gamma_s)}}$$

دائما الـ T_1 الكبيره جهه الـ *moment*

Design Bi-Axial Moment M_X, M_Y, P

1- Design using (Biaxial Bending Interaction Diagram)

Use **ECCS Page (5-9) ⟶ (5-24)**

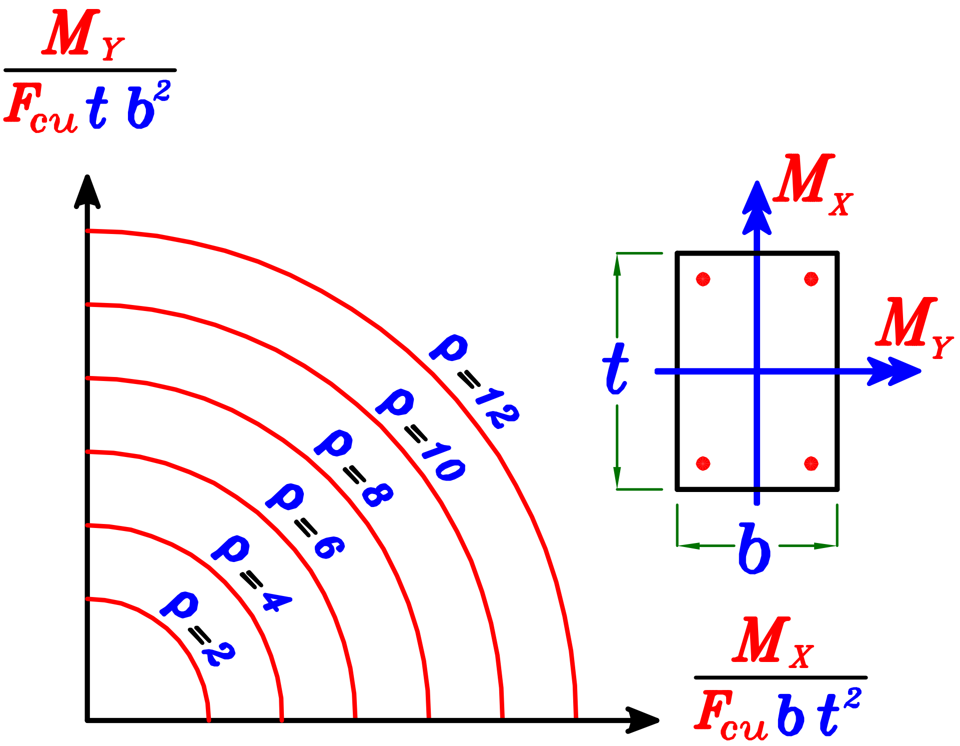


Chart Key

$F_y = \checkmark$

$R_b = \frac{P}{F_{cu}\, b\, t}$

$\zeta = \checkmark$

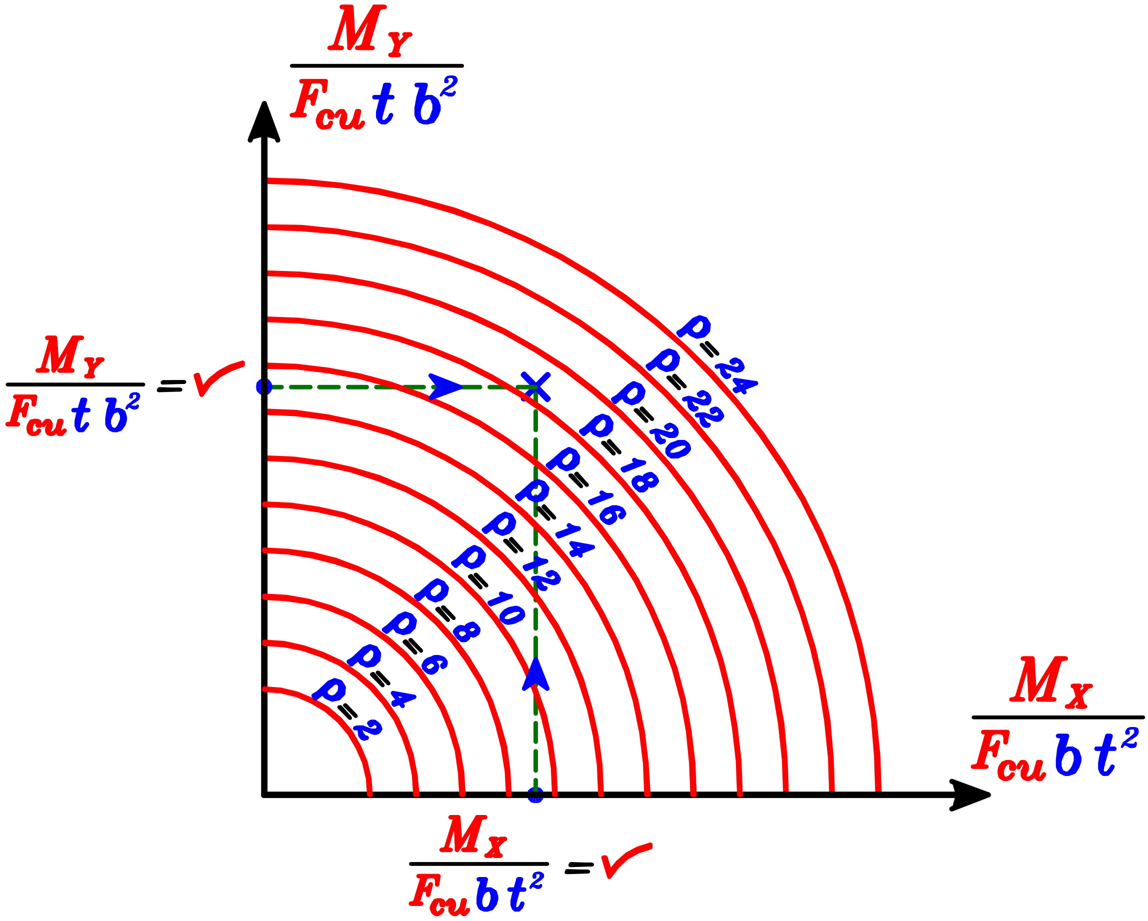
لتحديد أى Chart سيستخدم نحدد قيمه كل من F_y , R_b , ζ

$$R_b = \frac{P}{F_{cu}\, b\, t}$$

$\zeta = \frac{t - 2\,Cover}{t} = 0.9$ لانها القيمه الوحيده الموجوده فى الجداول

بعد تحديد ال Curve بمعرفه كل من F_y , R_b , ζ

نحدد قيمه كل من $\boxed{\frac{M_Y}{F_{cu}\, t\, b^2}}$, $\boxed{\frac{M_X}{F_{cu}\, b\, t^2}}$



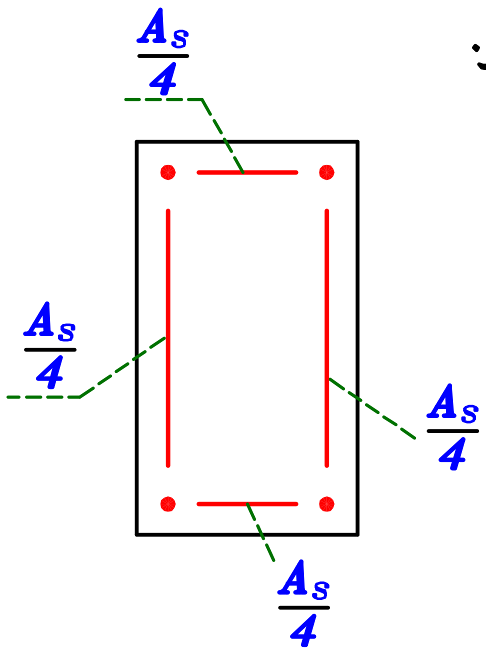
ثم نحدد قيمة ρ كما هو موضح

ثم نعوض فى المعادلات الأتيه لتحديد قيمه $A_{s\,total}$

$$A_{s\,total} = \mu * b * t$$
$$= \rho * F_{cu} * 10^{-4}$$

$$A_{s\,min} = \frac{0.8}{100} * b * t$$

نقارن $A_{s\,total}$ بال $A_{s\,min}$ و نضع القيمه الاكبر.



و يجب أن يكون عدد الاسياخ يقبل القسمه على ٤

نضع أربع أسياخ فى الاركان

ثم يقسم باقى الحديد بالتساوى على الاربع جهات

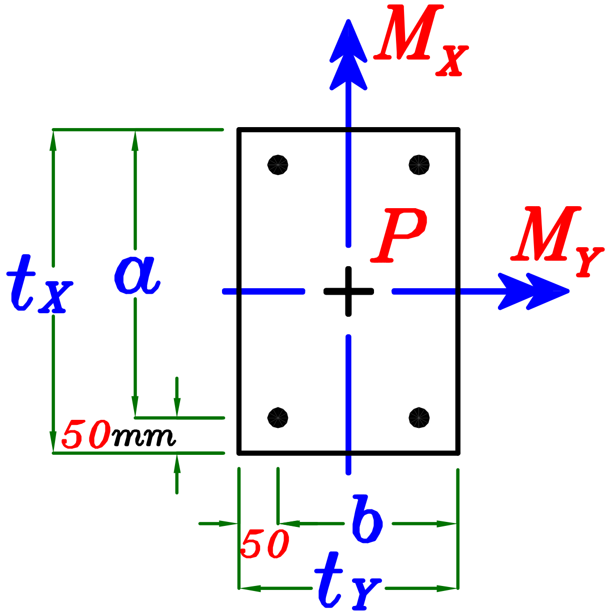
Symmetrical RFT.

2- Design using (Uniaxial Bending Interaction Diagram)
(Symmetrical arrangement of reinforcement)

طريقه أخرى تعتمد على تحويل تأثير العزمين الى عزم واحد فقط مكافئ لهم.

نحدد قيمه d التى تقاوم M_X و تسمى مثلا a

$$\boxed{a = t_X - 50\ mm}$$



نحدد قيمه d التى تقاوم M_Y و تسمى مثلا b

$$\boxed{b = t_Y - 50\ mm}$$

نحدد العزم الذى سيكون تأثيره اقل على القطاع و نهمله و نأخذ العزم الذى تأثيره اكبر على القطاع و نعمل على تكبيره لكن يكون مكافئ للعزمين معا .

و لمعرفه اى عزم سيتم اهماله و ايهم سيتم تكبيره نحسب نسبه كل عزم على ال d التى ستقاومه .

Calculate $\dfrac{M_X}{a}$, $\dfrac{M_Y}{b}$

We have two cases:

① IF $\dfrac{M_X}{a} > \dfrac{M_Y}{b} \xrightarrow{\text{Neglect}} M_Y \xrightarrow{\text{And Calculate}} M_X`$

② IF $\dfrac{M_Y}{b} > \dfrac{M_X}{a} \xrightarrow{\text{Neglect}} M_X \xrightarrow{\text{And Calculate}} M_Y`$

① IF $\frac{M_X}{a} > \frac{M_Y}{b}$ $\xrightarrow{\text{Neglect}}$ M_Y $\xrightarrow{\text{And Calculate}}$ $M_{X}^{`}$

Where: $$\boxed{M_{X}^{`} = M_X + \beta \frac{a}{b} M_Y}$$

$$\boxed{\beta = 0.9 - \frac{R_b}{2}}$$ --- $0.6 \leqslant \beta \leqslant 0.8$

IF $\beta < 0.6$ $\longrightarrow$ Take $\beta = 0.6$

IF $\beta > 0.8$ $\longrightarrow$ Take $\beta = 0.8$

Where R_b is the Load Level $R_b = \frac{P}{F_{cu}\, b\, t}$

Or we can use table in Code Page (6-59)

R_b	$\leqslant 0.2$	0.3	0.4	0.5	$\geqslant 0.6$
β	0.80	0.75	0.70	0.65	0.60

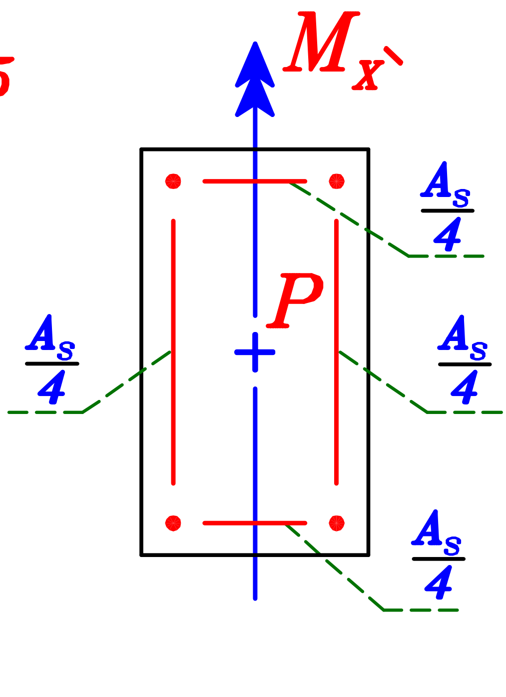
design the section on $P, M_{X}^{`}$

Using Uniaxial I.D. even IF $\frac{e}{t} > 0.5$

Then get $A_s = A_{s}^{`}$

$A_{s\,total} = A_s + A_{s}^{`}$

Check $A_{s\,total}$ with $\boxed{A_{s\,min} = \frac{0.8}{100} * b * t}$



نضع أربع أسياخ فى الاركان

ثم يقسم باقى الحديد بالتساوى على الاربع جهات

② IF $\frac{M_Y}{b} > \frac{M_X}{a} \xrightarrow{\text{Neglect}} M_X \xrightarrow{\text{And Calculate}} M_{Y`}$

Where: $$\boxed{M_{Y`} = M_X + \beta \, \frac{b}{a} \, M_X}$$

β is the same as before.

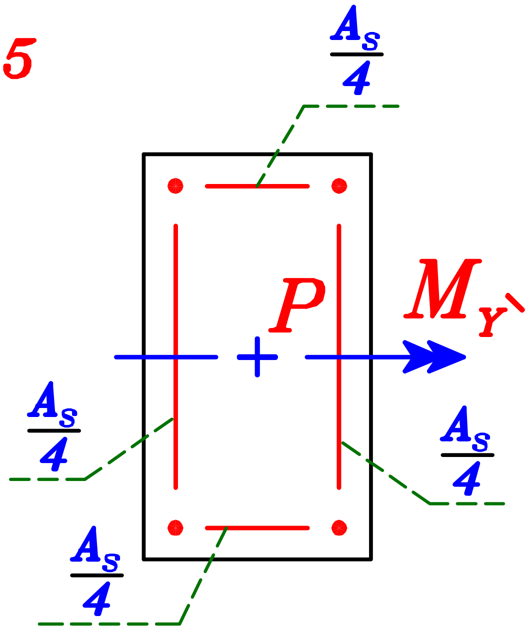
design the section on $P, M_{X`}$

Using Uniaxial I.D. even IF $\frac{e}{t} > 0.5$

Then get $A_s = A_{s`}$

$A_{s\,total} = A_s + A_{s`}$

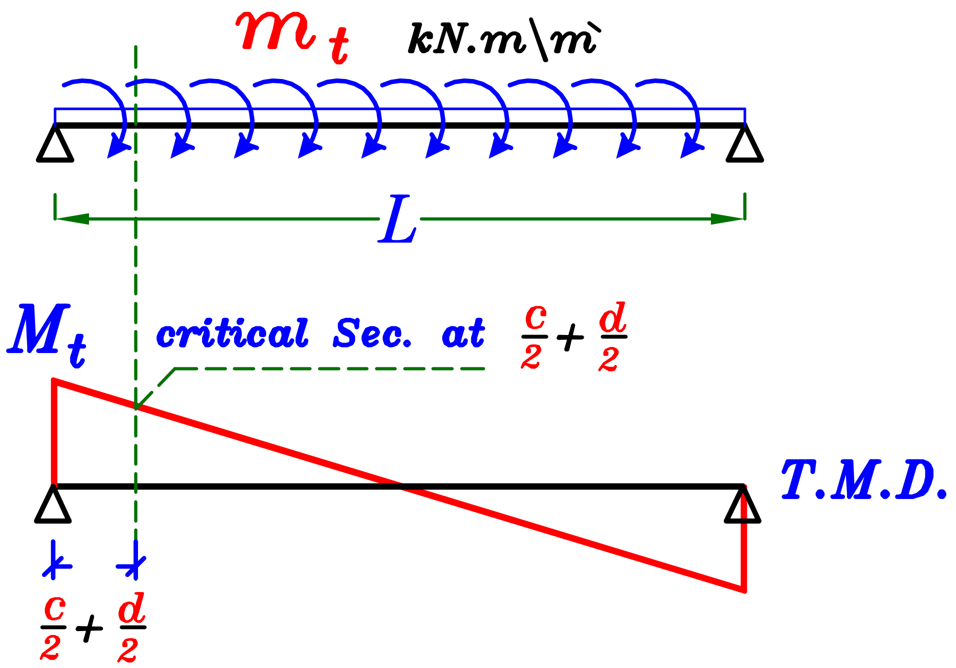
Check $A_{s\,total}$ with $\boxed{A_{s\,min} = \frac{0.8}{100} * b * t}$



نضع أربع أسياخ فى الاركان

Torsion Revision.

Shear Stress due to Torsional moment. (q_{tu})



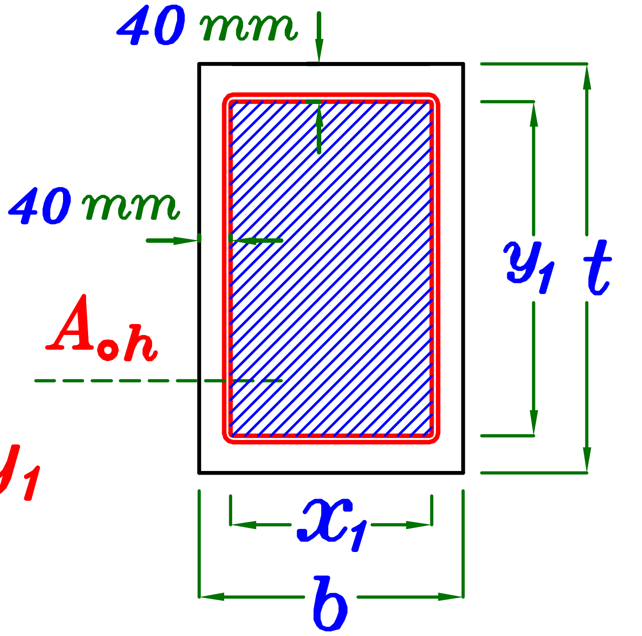
$$\boxed{q_{tu} = \frac{M_{tu}}{2\,A_o\,t_e}} \quad (N\backslash mm^2)$$

Where:

* q_{tu} $(N\backslash mm^2)$ = Actual Shear Stress due to Torsional Moment.
* M_{tu} $(N.mm)$ = Torsional Moment at Critical Section.
* A_{oh} (mm^2) = Torsion المساحه الداخليه للكانه المقاومه لل
* A_o (mm^2) = $0.85 * A_{oh}$
* P_h (mm) = Torsion محيط الكانه المقاومه لل
* t_e (mm) = $\dfrac{\text{المساحه الداخليه للكانه}}{\text{محيط الكانه}} = \dfrac{A_{oh}}{P_h}$

* $y_1 = t - 2\ Cover \simeq t - 80\ mm$

* $x_1 = b - 2\ Cover \simeq b - 80\ mm$



For R-Sec.

A_{oh} = المساحه الداخليه للكانه $= x_1 * y_1$

P_h = محيط الكانه $= 2\,(x_1 + y_1)$

$$t_e = \frac{\text{المساحه الداخليه للكانه}}{\text{محيط الكانه}} = \frac{x_1 * y_1}{2\,(x_1 + y_1)}$$

$$\therefore \boxed{q_{tu} = \frac{M_{tu}}{2\,A_o\,t_e} = \frac{M_{tu}\,(x_1 + y_1)}{0.85\,(x_1^2 * y_1^2)}}$$

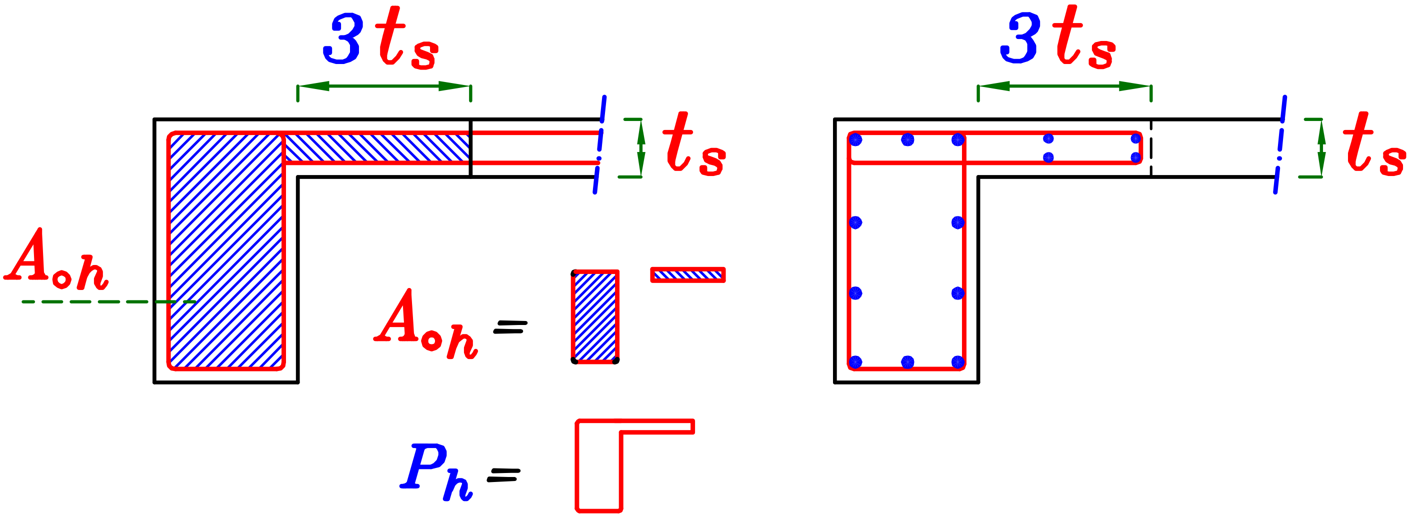
For R-Sec. only

For L-Sec.

عند وجود بلاطه مع الكمره من الممكن أن نعتبر أن جزء من البلاطه يقاوم

الـ Torsion مع الكمره . و هذا الجزء يساوى تقريبا $3t_s$

بشرط ان يوضع فى هذا الجزء كانات لمقاومه الـ Torsion



Check Shear + Torsion.

Actual Stresses due to Shear Force. q_u

$$\boxed{q_u = \frac{Q}{b\,d}}$$

Actual Stresses due to Torsional Moment. q_{tu}

$$\boxed{q_{tu} = \frac{M_{tu}}{2A_o t_e}}$$

---

min. allowable stresses due to Shear q_{cu}

$$\boxed{q_{cu} = (0.24)\sqrt{\frac{F_{cu}}{\gamma_c}}}$$

min. allowable stresses due to Torsion q_{tu}

$$\boxed{q_{t\,min} = (0.06)\sqrt{\frac{F_{cu}}{\gamma_c}}}$$

---

max. allowable shear stresses $q_{u\,max}$

$$\boxed{q_{u\,max} = (0.70)\sqrt{\frac{F_{cu}}{\gamma_c}}}$$

IF $\sqrt{q_u^2 + q_{tu}^2} > q_{u\,max} \longrightarrow$ Increase Dimensions

For Box Sections only.

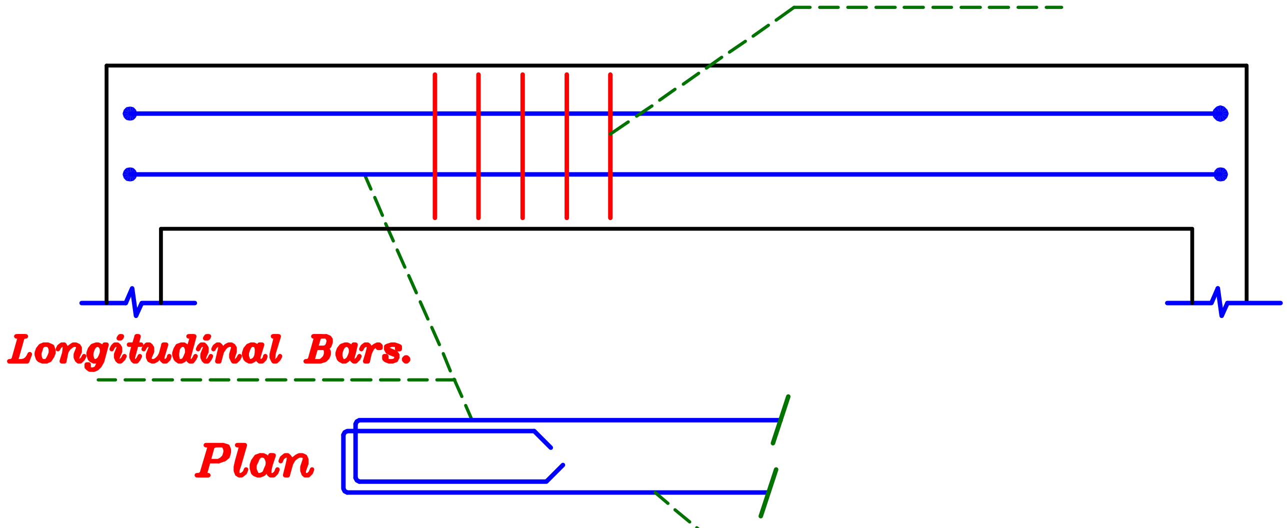
IF $q_u + q_{tu} > q_{u\,max} \longrightarrow$ Increase Dimensions

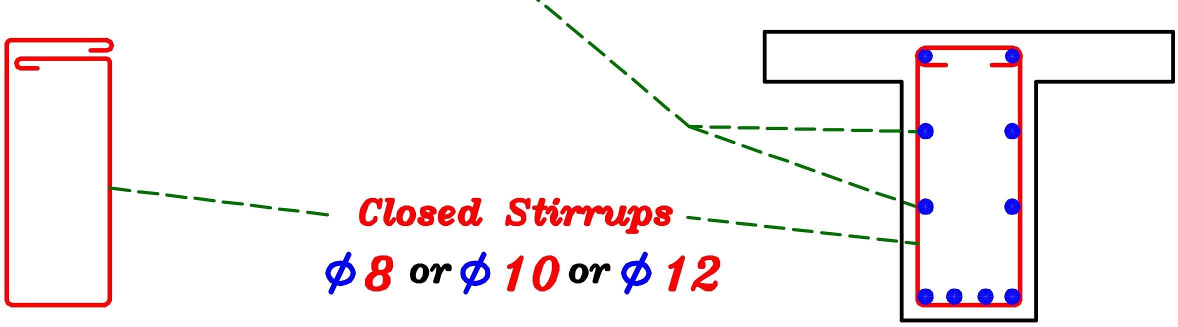
$$\text{IF } \sqrt{q_u^2 + q_{tu}^2} \leq q_{u\,max}$$

	q_u	q_{tu}	RFT.
1	$q_u < q_{cu}$	$q_{tu} < q_{t\,min}$	Use Stirrups $5\phi 8 \backslash m'$
2	$q_u > q_{cu}$	$q_{tu} < q_{t\,min}$	Use RFT. to resist $\left(q_u - \frac{q_{cu}}{2}\right)$
3	$q_u < q_{cu}$	$q_{tu} > q_{t\,min}$	Use RFT. to resist (q_{tu})
4	$q_u > q_{cu}$	$q_{tu} > q_{t\,min}$	Use RFT. to resist $\left(q_u - \frac{q_{cu}}{2}\right) + (q_{tu})$

How to Resist Torsion ??

1. Closed Stirrups. ١ كانات مغلقة .
2. Longitudinal Bars. ٢ أسياخ طوليه .





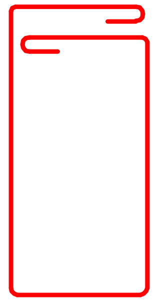
Case ③ $q_u < q_{cu}$, $q_{tu} > q_{t\,min}$

Use Shear RFT. to resist Shear Stresses $\left(q_{tu} - \frac{q_{t\,min}}{2}\right)$ *applied From Torsional moment.*

① Closed Stirrups.

$$\boxed{A_{str} = \frac{M_{tu}\ S_t}{(1.7)\ A_{oh}\left(\frac{F_y}{\gamma_s}\right)}}$$

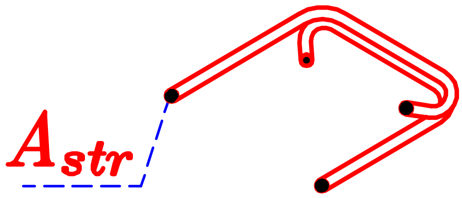
حفظ



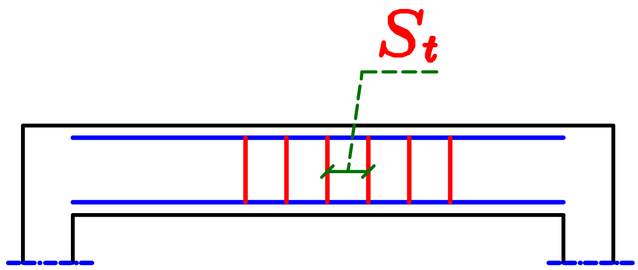
Closed Stirrup

Where:

* A_{str} مساحه مقطع سيخ الكانه



ϕ	A_{str}
$\phi\,8$	$50.3\ mm^2$
$\phi\,10$	$78.5\ mm^2$
$\phi\,12$	$113\ mm^2$



ملحوظه .

- ممكن إستخدام كانات حتى $\phi\,12$ فى ال **Torsion**
- كانات ال **Torsion** تكون الكانات الخارجيه فقط .

* S_t المسافه الطوليه بين كانات ال **Torsion**

$$S_t = (100\ mm \longrightarrow 200\ mm)$$

In the equation choose $\phi \longrightarrow A_{str} = \checkmark$

Then get $S_t = (100\ mm \longrightarrow 200\ mm)$

- IF $S_t \geqslant 200\ mm \xrightarrow{use} 5\phi \checkmark \setminus m'$
- IF $S_t < 100\ mm$ Choose bigger ϕ
- IF $100\ mm < S_t < 200\ mm \xrightarrow{Get}$ No of stirrups $\setminus m' = \dfrac{1000}{S_t}$

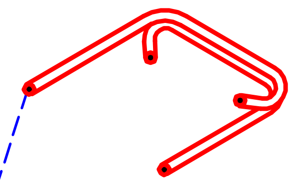
---

② Longitudinal Bars.

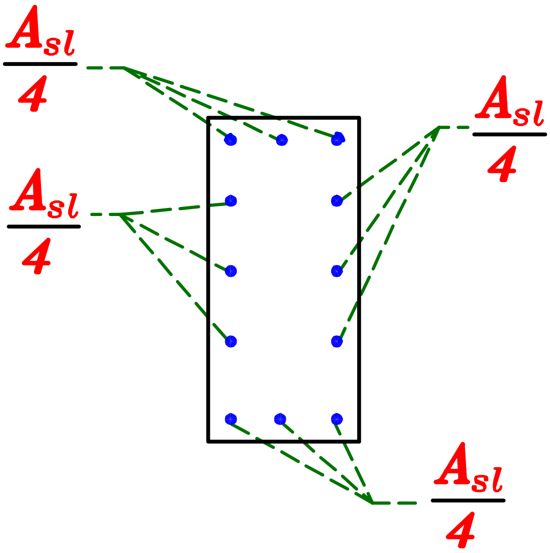
$$\boxed{A_{sl} = \frac{A_{str} * P_h}{S_t} \left(\frac{F_{y\ str.}}{F_{y\ L.b.}} \right)}$$

Where:

* A_{sl} مجموع مساحه مقطع الأسياخ الطوليه كلها.
* A_{str} مساحه مقطع سيخ الكانه. A_{str}

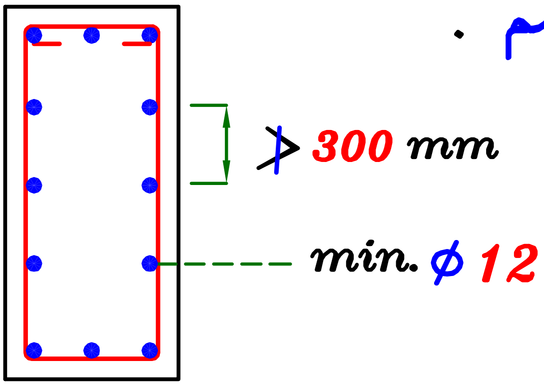


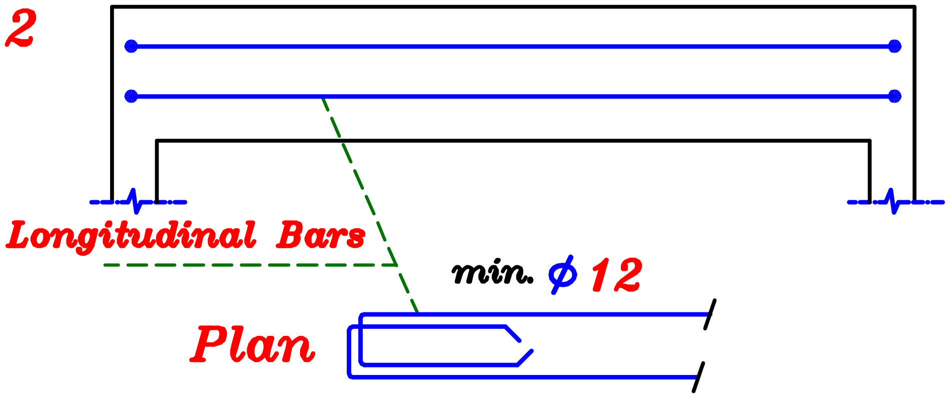
* $F_{y\ str.} = F_y$ For stirrups. $\simeq 240\ N\setminus mm^2$
* $F_{y\ L.b.} = F_y$ For Longitudinal bars. $\simeq 360\ N\setminus mm^2$



- توزع الأسياخ على محيط القطاع بانتظام .

- المسافه بين الأسياخ لا تزيد عن ٣٠٠ مم .
- أقل قطر للسيخ $\phi\ 12$





اذاً لرص تسليح ال **Longitudinal Bars**

يتم زياده مساحه $\frac{A_{sl}}{4}$ على مساحه التسليح الرئيسى للعزوم

ثم نحدد بعدها عدد الاسياخ الكليه و اقطارها .

يتم زياده مساحه $\frac{A_{sl}}{4}$ على مساحه ال **Stirrup Hangers**

ثم نحدد بعدها عدد الاسياخ الكليه و اقطارها .

يتم وضع اسياخ جانبيه بدل ال **Shrinkage Bars**

قيمتها $1\ \phi\ 12$ كل ٣٠٠ مم و توضع حتى لو كان $t < 700\ mm$

Case ④ $q_u > q_{cu}$, $q_{tu} > q_{t\,min}$

Use Shear RFT. to resist Shear Stresses (q_{tu}) applied From Torsional moment.

+ Shear RFT. to resist Shear Stresses $\left(q_u - \frac{q_{cu}}{2}\right)$ applied From Shear Force.

① Closed Stirrups.

ⓐ Torsion.

$$\boxed{A_{str} = \frac{M_{tu}\ S_t}{(1.7)\ A_{oh}\left(\frac{F_y}{\gamma_s}\right)}} \longrightarrow A_{str} = \checkmark * S \quad \text{---} ①$$

كانات خارجيه فقط

A_{str} هى مساحه سيخ الكانه الخارجيه التى نحتاجها لمقاومه ال Torsion فقط.

ⓑ Shear.

$$\boxed{q_u - \frac{q_{cu}}{2} = \frac{n\ A_s (F_y \backslash \gamma_s)}{b\ \ S_s}} \longrightarrow A_s = \checkmark * \frac{S}{n} \quad \text{---} ②$$

كانات خارجيه و ممكن كانات داخليه

A_s هى مساحه مقطع سيخ واحد من الكانه الخارجيه أو الداخليه التى نحتاجها لمقاومه ال Shear فقط.

– نبدأ أولاً بفرض أن عدد فروع الكانه يساوى فرعين $n = 2$ و عدد الكانات فى المتر = من (٥ ⟵ ١٠) أسياخ/م ثم نحسب $S = \frac{1000}{No\ \ of\ \ st.\backslash m}$ ثم نحسب A_{str} , A_s

و تكون مساحه السيخ من الكانات الخارجيه $A_{s_{outer}} = A_{str} + A_s$

– فاذا كانت $113\ mm^2 \geqslant A_{s_{outer}}$ أى أن $\phi 12 \geqslant \phi_{Outer}$

فنختار $\phi 12$ or $\phi 10$ or $\phi 8 = \phi_{Outer}$ و لا توجد كانات داخليه

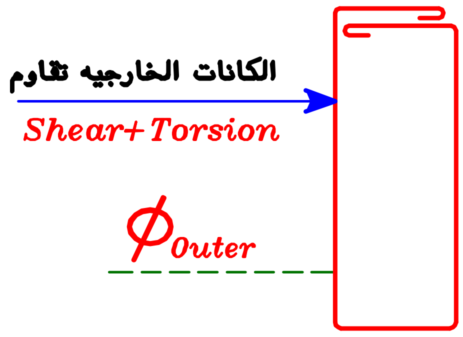
– أما اذا كانت $113\ mm^2 < A_{s_{outer}}$ فنختار عدد كانات أكثر فى المتر أو نأخذ $n = 4$

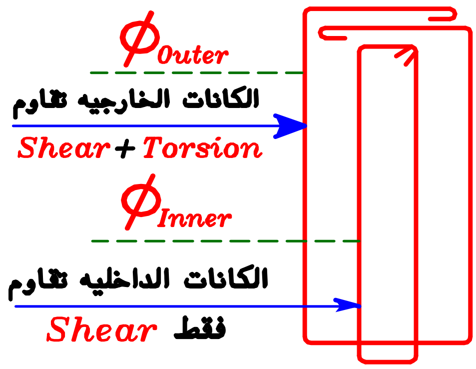
ثم تحديد قيمه A_s و تحديد قيمه $A_{s_{outer}} = A_{str} + A_s$

و تحديد قيمه $A_{s_{inner}} = A_s$

ترتيب اختيار الفروض لـ n , S

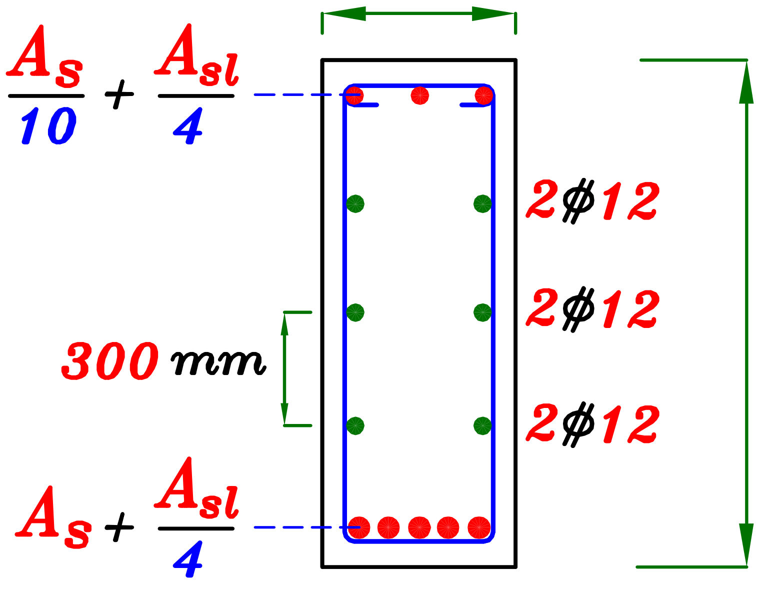
Assumption No.	n	No. of stirrups\m	$S_s = S_t$ (mm)
1	2	5.0	$\frac{1000}{5.0}$
2	2	6.0	$\frac{1000}{6.0}$
3	2	7.0	$\frac{1000}{7.0}$
4	2	8.0	$\frac{1000}{8.0}$
5	2	9.0	$\frac{1000}{9.0}$
6	2	10	$\frac{1000}{10}$
7	4	5.0	$\frac{1000}{5.0}$
8	4	6.0	$\frac{1000}{6.0}$
9	4	7.0	$\frac{1000}{7.0}$
10	4	8.0	$\frac{1000}{8.0}$
11	4	9.0	$\frac{1000}{9.0}$
12	4	10	$\frac{1000}{10}$



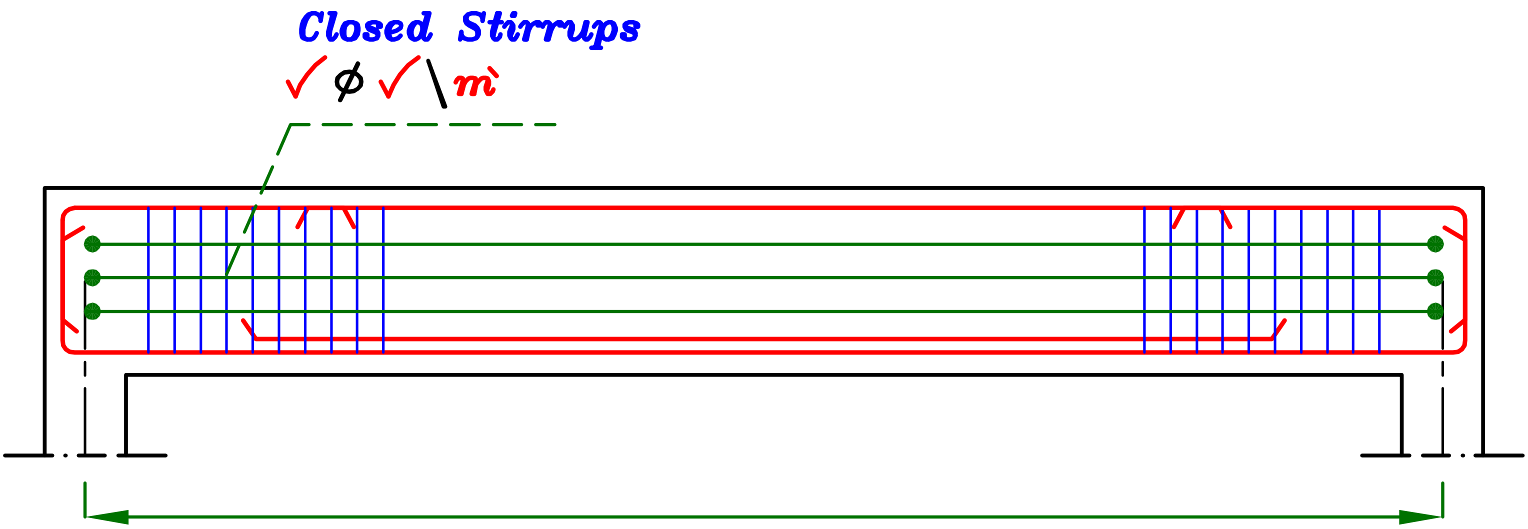


② Longitudinal Bars. Torsion only

$$A_{sl} = \frac{A_{str} * P_h}{S_t} \left(\frac{F_{y\,str.}}{F_{y\,L.b.}} \right)$$



$\frac{A_s}{10} + \frac{A_{sl}}{4}$
2φ12
2φ12
2φ12
300 mm
$A_s + \frac{A_{sl}}{4}$



Closed Stirrups
✓φ✓\m`

Example.

For the shown surface of revolution, It is required to:

1- Calculate the internal Forces at the critical sections.

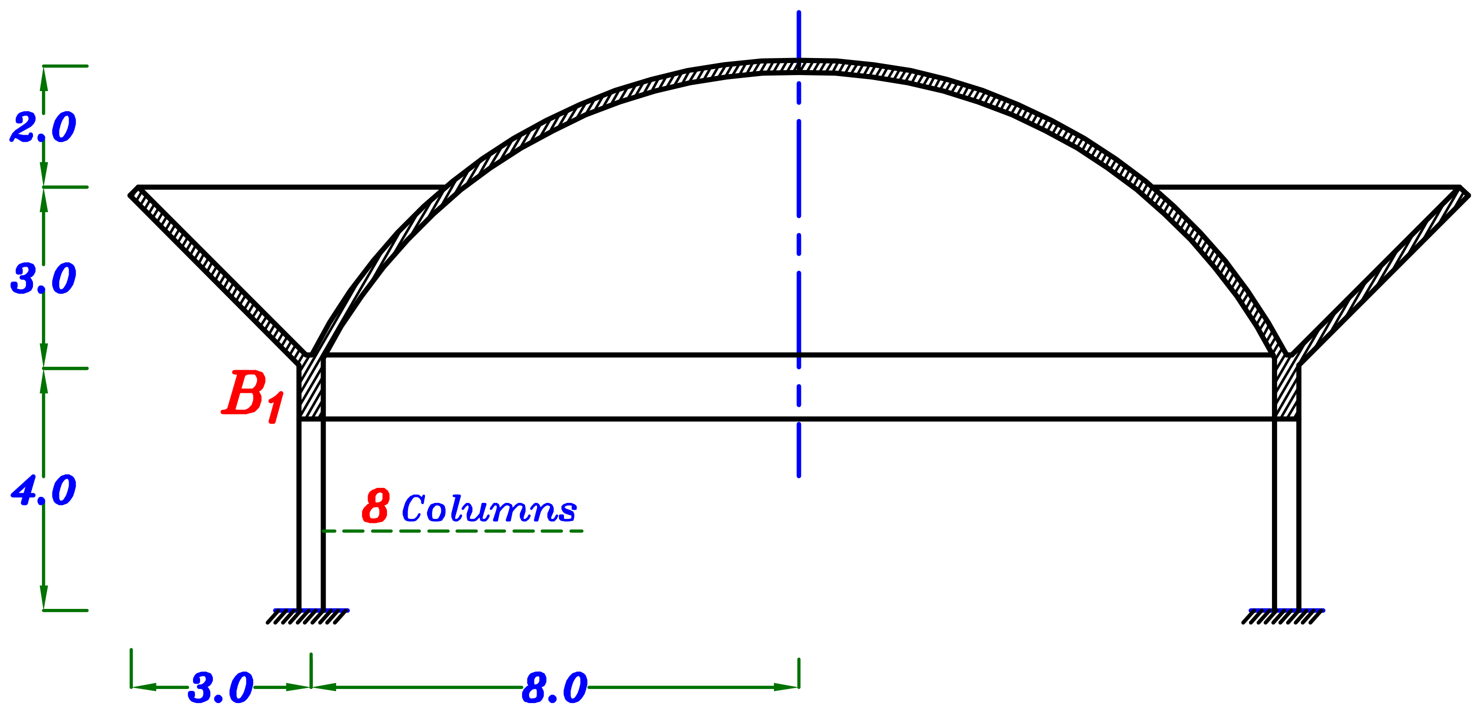
2- Design the surface of revolution and draw details of RFT. in plan and cross sections.

3- Design the supporting beam (B_1) and draw its RFT. in elevation and Cross Sections.

Given:

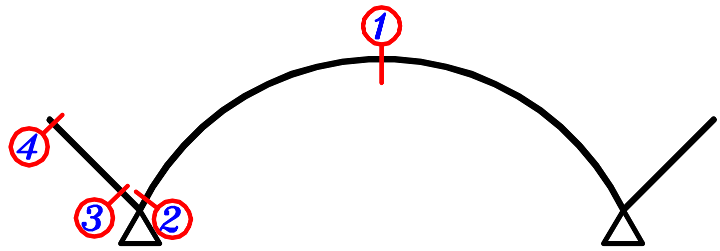
F.C. = 0.50 kN/m^2 , L.L. = 0.50 kN/m^2 (H.P.)

F_{cu} = 25 N/mm^2 , st. 360/520



Solution.

Choose $t_s = 100\ mm \longrightarrow 140\ mm$



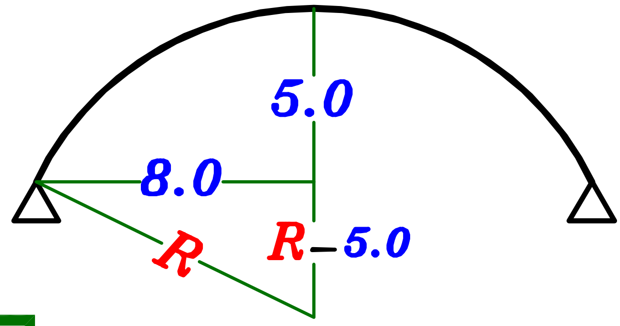
Take $\boxed{t_s = 100\ mm}$

Loads.

$$g_s = t_s\, \gamma_c + F.C. = 0.10 * 25 + 0.50 = 3.0\ kN/m^2$$

$$p_s = 0.5\ kN/m^2$$

For the Dome.



$$R^2 = 8.0^2 + (R - 5.0)^2$$

$$\cancel{R^2} = 64 + \cancel{R^2} - 10.0\ R + 25.0$$

$$10\ R = 89.0 \longrightarrow \boxed{R = 8.90\ m}$$

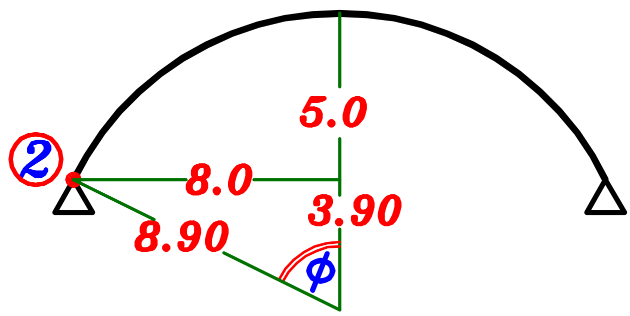
Sec. 1 Dome Vertex $\phi = Zero$

$$Z = g\ Cos\,\phi + p\ Cos^2\phi$$

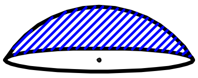
$$= 3.0 * Cos\,0.0 + 0.5 * Cos^2 0.0 = +3.5\ kN/m^2$$

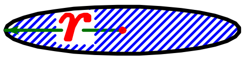
$$(T_1)_1 = (T_2)_1 = \frac{R\,Z}{2} = \frac{8.90 * 3.5}{2} = +\ 15.58\ kN/m\ Comp.$$

Sec. 2



$$Sin\,\phi = \frac{8.0}{8.90} \longrightarrow \boxed{\phi = 64.01^\circ}$$

$S.A. = 2\pi * R * h$  $= 2\pi * 8.90 * 5.0 = 279.6\ m^2$

$Projected\ area = \pi * r^2$  $= \pi * 8.0^2 = 201.07\ m^2$

$W_\phi = g * S.A. + p * Projected\ area$

$= 3.0 * 279.6 + 0.5 * 201.07 = +939.33\ kN$

$(T_1)_2 = \dfrac{W_\phi}{2\pi r\ Sin\phi} = \dfrac{+939.33}{2\pi * 8.0 * Sin\ 64.01^\circ} = +\ 20.79\ kN/m$ **Comp.**

$R_1 = R_2 = R = 8.90\ m$

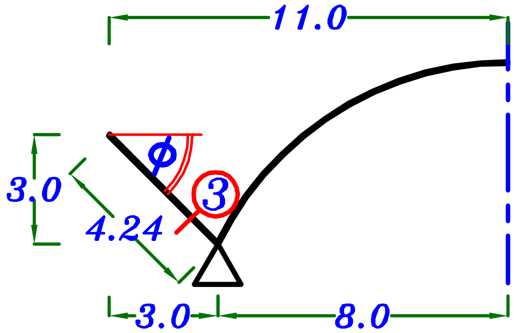
$Z = g\ Cos\phi + p\ Cos^2\phi$

$= 3.0 * Cos\ 64.01 + 0.5 * Cos^2\ 64.01 = +1.41\ kN/m^2$

$\because\ T_1 + T_2 = Z * R \qquad \therefore\ +20.79 + T_2 = 1.41 * 8.90$

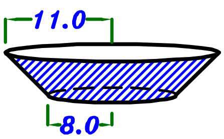
$\therefore\ (T_2)_2 = -\ 8.24\ kN/m$ **Ten.**

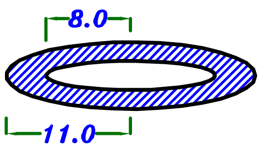
For the Cone.



$tan\phi = \dfrac{3.0}{3.0} \longrightarrow \boxed{\phi = 45.0^\circ}$

Sec. 3 $\quad r = 8.0\ m$

$S.A. = \pi * L\ (a+b)$  $= \pi * 4.24 * (11.0 + 8.0) = 253.08\ m^2$

$Projected\ area = \pi * (r_1^2 - r_2^2)$  $= \pi * (11.0^2 - 8.0^2)$

$= 179.07\ m^2$

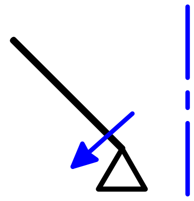
$W_\phi = g * S.A. + p * Projected\ area$

$= 3.0 * 253.08 + 0.5 * 179.07 = +848.77\ kN$

$$(T_1)_3 = \frac{W_\phi}{2\pi r \; Sin\phi} = \frac{+848.77}{2\pi * 8.0 * Sin\,45^\circ} = +\,23.88 \;\; kN/m \;\; Comp.$$

$$Z = g\;Cos\,\phi + p\;Cos^2\phi = 3.0 * Cos\,45 + 0.5 * Cos^2 45 = -2.37\; kN/m^2$$

$\boxed{\text{اشاره } Z \text{ } (-Ve) \text{ لان اتجاهها خارج من المحور}}$



$$R_2 = \frac{r}{Sin\phi} = \frac{8.0}{Sin\,45^\circ} = 11.31\; m$$

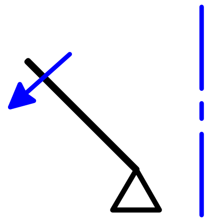
$$\because\; (T_2)_3 = Z * R_2 = -2.37 * 11.31 = -\,26.80\; kN/m \;\; Ten.$$

Sec. 4

$$r = 11.0\; m$$

$$W_\phi = Zero \longrightarrow (T_2)_4 = Zero$$

$$Z = g\;Cos\,\phi + p\;Cos^2\phi = 3.0 * Cos\,45 + 0.5 * Cos^2 45 = -2.37\; kN/m^2$$



$$R_2 = \frac{r}{Sin\phi} = \frac{11.0}{Sin\,45^\circ} = 15.55\; m$$

$$(T_2)_4 = Z * R_2 = -2.37 * 15.55 = -36.85\; kN/m \;\; Ten.$$

Design of Sections.

For the Dome. Sec. ① & Sec. ②

$(T_{max}) = 20.79$ kN/m Comp.

$$\text{Actual Stress} = \frac{T_{max}}{A_c} = \frac{T_{max}}{1000 * t_s} = \frac{20.79 * 10^3}{1000 * 100} = 0.208 \ N/mm^2$$

$$F_{cu} = 25 \ N/mm^2 \longrightarrow F_{co} = 6.0 \ N/mm^2$$

$$\text{Allawable Stress} = \frac{F_{co}}{2} = \frac{6.0}{2} = 3.0 \ N/mm^2$$

Actual Stress < Allawable Stress $\longrightarrow$ $t_s = 100$ mm is o.k.

To Get T_1 RFT. $\longrightarrow$ No Tension $\xrightarrow{\text{use min. RFT.}}$ $5 \phi 10 \backslash m'$ each Side

To Get T_2 RFT. $\longrightarrow$ max. Tension $T_2 = 8.24$ kN/m

$$A_{s(T_2)} = \frac{T_{2\,(U.L.)}}{F_y \backslash \gamma_s} = \frac{1.5 * 8.24 * 10^3}{360 \backslash 1.15} = 39.48 \ mm^2/m$$

$$A_{s(T_2)} \backslash Side = \frac{39.48}{2} = 19.74 \ mm^2/m \xrightarrow{\text{use min. RFT.}} 5 \phi 10 \backslash m' \text{ each Side}$$

For the Cone. Sec. ③ & Sec. ④

$(T_{max}) = 23.88$ kN/m Comp.

$$\text{Actual Stress} = \frac{T_{max}}{A_c} = \frac{T_{max}}{1000 * t_s} = \frac{23.88 * 10^3}{1000 * 100} = 0.239 \ N/mm^2$$

$$\text{Allawable Stress} = \frac{F_{co}}{2} = \frac{6.0}{2} = 3.0 \ N/mm^2$$

Actual Stress < Allawable Stress $\longrightarrow$ $t_s = 100$ mm is o.k.

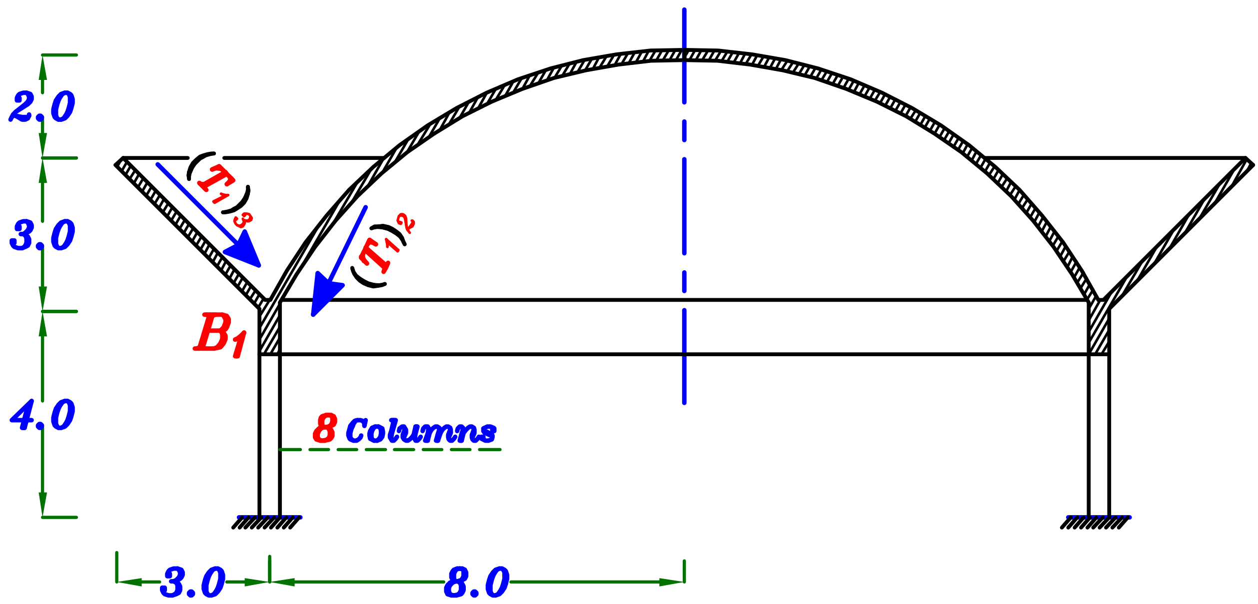
To Get T_1 RFT. $\longrightarrow$ No Tension $\xrightarrow{\text{use min. RFT.}}$ $5 \phi 10 \backslash m'$ each Side

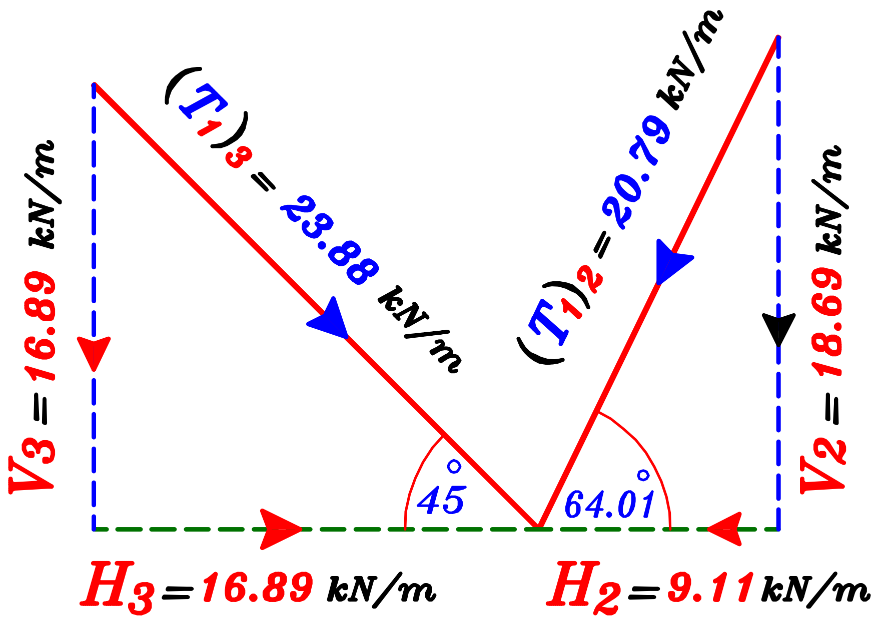
To Get T_2 RFT. $\longrightarrow$ max. Tension $T_2 = 36.85$ kN/m

$$A_{s(T_2)} = \frac{T_{2\,(U.L.)}}{F_y \backslash \gamma_s} = \frac{1.5 * 36.85 * 10^3}{360 \backslash 1.15} = 176.5 \ mm^2/m$$

$$A_{s(T_2)} \backslash Side = \frac{176.5}{2} = 88.25 \ mm^2/m \xrightarrow{\text{use min. RFT.}} 5 \phi 10 \backslash m' \text{ each Side}$$

Loads on Beam B_1





$$L = \frac{2\pi r}{n} = \frac{2 * \pi * 8}{8} = 6.28 \text{ m}$$

$$t = \frac{L}{12} + 0.2 \text{ m} = \frac{6.28}{12} + 0.2 = 0.72 = 0.75 \text{ m}$$

Take B_1 (300*750)

$$o.w._{(beam)} = b * t * \gamma_c = 0.30 * 0.75 * 25 = 5.62 \text{ kN/m}$$

$$w = o.w. + V_2 + V_3 = 5.62 + 18.69 + 16.89 = 41.20 \text{ kN/m}$$

$H = H_3 - H_2 = 16.89 - 9.11 = 7.78$ kN/m للداخل

$$\text{Normal Force on Beam} = H * r = 7.78 * 8.0 = 62.24 \text{ kN}$$

From Tables

No. of supports	Load on each support	Max. Shearing Force	Max. Bending Moment at C.L. of Span	Max. Bending Moment Over C.L. of Column	Max. Torsional Moment	Central angle
n	R	$Q_{max.}$	M_{+Ve}	M_{-Ve}	$M_{t\,max.}$	θ
4	P/4	P/8	0.0176 Pr	– 0.0322 Pr	0.0053 Pr	19° 21`
6	P/6	P/12	0.0075 Pr	– 0.0148 Pr	0.0015 Pr	12° 44`
8	P/8	P/16	0.0042 Pr	– 0.0083 Pr	0.0006 Pr	9° 33`
10	P/10	P/20	0.0032 Pr	– 0.0052 Pr	0.0004 Pr	7° 36`
12	P/12	P/24	0.0019 Pr	– 0.0037 Pr	0.0002 Pr	6° 21`

$n = 8.0$

$P = w * 2\pi r = 41.20 * 2\pi * 8.0 = 2070.93$ kN

max. $M_{+Ve} = 0.0042\, Pr = 0.0042 * 2070.93 * 8.0 = 69.58$ kN.m

max. $M_{-Ve} = 0.0083\, Pr = 0.0083 * 2070.93 * 8.0 = 137.51$ kN.m

max. $M_t = 0.0006\, Pr = 0.0006 * 2070.93 * 8.0 = 9.94$ kN.m

$$Q_{max.} = \frac{P}{16} = \frac{2070.93}{16} = 129.43 \text{ kN}$$

Central angle $\theta = 9^\circ\ 33` = 9.55^\circ$

$$X = r * \theta * \frac{\pi}{180} = 8.0 * 9.55 * \frac{\pi}{180} = 1.33 \text{ m}$$

$Q_{cor.} = Q_{max} - w * X = 129.43 - 41.20 * 1.33 = 74.63$ kN

Design beam B_1 on M & P

$b = 300$ mm , $t = 750$ mm

Sec. of max. $-$Ve B.M.

$M = 137.51 * 1.5 = 206.26$ kN.m. , $P = 62.24 * 1.5 = 93.36$ kN

Check $\frac{P}{F_{cu}\, b t} = \frac{93.36 * 10^3}{25 * 300 * 750} = 0.016 < 0.04$ (Neglect P)

$\therefore\ d = C_1 \sqrt{\frac{M_{U.L.}}{F_{cu}\, b}}$ $\therefore\ 700 = C_1 \sqrt{\frac{206.26 * 10^6}{25 * 300}} \rightarrow C_1 = 4.22 \rightarrow J = 0.810$

$$\therefore A_s = \frac{M_{U.L.}}{J\, F_y\, d} = \frac{206.26 * 10^6}{0.810 * 360 * 700} = 1010.5\ mm^2$$

Check $A_{s_{min.}}$ $A_{s_{req.}} = 1010.5\ mm^2$

$$\mu_{min.}\, b\, d = \left(0.225 * \frac{\sqrt{F_{cu}}}{F_y}\right) b\, d = \left(0.225 * \frac{\sqrt{25}}{360}\right) 300 * 700 = 656.25\ mm^2$$

$\therefore A_{s_{req.}} > \mu_{min.}\, b\, d$ $\therefore$ Take $A_s = A_{s_{req.}} = 1010.5\ mm^2$

Sec. of max. $+$Ve B.M.

$M = 69.58 * 1.5 = 104.37$ kN.m.

$\therefore\ d = C_1 \sqrt{\frac{M_{U.L.}}{F_{cu}\, b}}$ $\therefore\ 700 = C_1 \sqrt{\frac{104.37 * 10^6}{25 * 300}} \rightarrow C_1 = 5.93 \rightarrow J = 0.826$

$$\therefore A_s = \frac{M_{U.L.}}{J\, F_y\, d} = \frac{104.37 * 10^6}{0.826 * 360 * 700} = 501.4\ mm^2$$

Check $A_{s_{min.}}$ $A_{s_{req.}} = 501.4\ mm^2$

$$\mu_{min.}\, b\, d = \left(0.225 * \frac{\sqrt{F_{cu}}}{F_y}\right) b\, d = \left(0.225 * \frac{\sqrt{25}}{360}\right) 300 * 700 = 656.25\ mm^2$$

$$\therefore \mu_{min.}\, b\, d > As_{req.} \xrightarrow{Use} As_{min.}$$

$$As_{min.} = 0.225 * \frac{\sqrt{F_{cu}}}{F_y}\, b\, d = \left(0.225 * \frac{\sqrt{25}}{360}\right) 300 * 700 = 656.25$$

$$1.3\, As_{req.} = 1.3 * 501.4 = 651.8$$

$$\left.\begin{matrix} 656.25 \\ 651.8 \end{matrix}\right\} \text{الأقل} = 651.8$$

st. 360/520 $\quad \frac{0.15}{100}\, b\, d = \frac{0.15}{100} * 300 * 700 = 315$

$$\left.\begin{matrix} 651.8 \\ 315 \end{matrix}\right\} \text{الأكبر} = 651.8\ mm^2$$

Design due to Shear & Torsion.

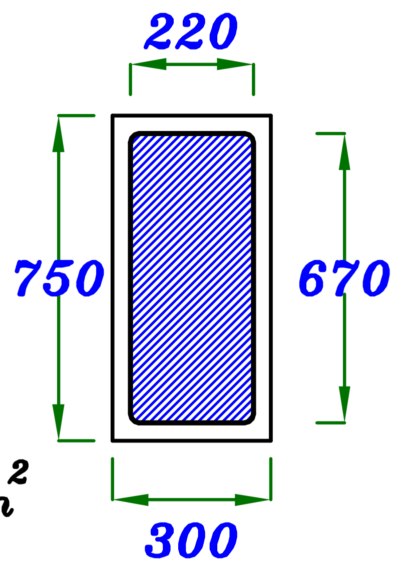
$$q_u = \frac{Q}{b\, d} = \frac{1.5 * 74.63 * 10^3}{300 * 700} = 0.533\ N/mm^2$$

$$A_{oh} = 220 * 670 = 147400\ mm^2$$

$$A_o = 0.85 * A_{oh} = 0.85 * 147400 = 125290\ mm^2$$

$$P_h = 2 * 220 + 2 * 670 = 1780\ mm$$

$$t_e = \frac{A_{oh}}{P_h} = \frac{147400}{1780} = 82.81\ mm$$



$$q_{tu} = \frac{M_{tu}}{2\, A_o\, t_e} = \frac{1.5 * 9.94 * 10^6}{2 * 125290 * 82.81} = 0.72\ N/mm^2$$

$$q_{cu} = (0.24)\sqrt{\frac{25}{1.5}} = 0.98\ N/mm^2$$

$$q_{t\,min} = (0.06)\sqrt{\frac{25}{1.5}} = 0.245\ N/mm^2$$

$$q_{u\,max} = (0.7)\sqrt{\frac{25}{1.5}} = 2.85\ N/mm^2$$

$$\sqrt{q_u^2 + q_{tu}^2} = \sqrt{0.533^2 + 0.72^2} = 0.896\ N/mm^2 < q_{u\,max} \quad \therefore o.k.$$

$$\boxed{q_u < q_{cu}\ ,\ q_{tu} > q_{t\,min}}$$

$\therefore$ Use RFT. For Torsion only.

* **Stirrups.**

$$\because A_{str} = \frac{M_{tu}\ S_t}{(1.7)\ A_{oh}\ \left(\frac{F_y}{\gamma_s}\right)} \qquad \therefore A_{str} = \frac{(1.5 * 9.94 * 10^6) * S_t}{(1.7)(147400)(240/1.15)}$$

$$\therefore \boxed{S_t = 3.507 * A_{str}}$$

* Take $\phi\ 8 \longrightarrow A_{str} = 50.3\ mm^2$

$$\therefore S_t = 3.507 * A_{str} = 3.507 * 50.3 = 176.4\ mm > 100\ mm \quad \therefore o.k.$$

$$\therefore \text{No. of stirrups}\backslash m' = \frac{1000}{S} = \frac{1000}{176.4} = 5.66 = 6.0$$

$\therefore$ Use Closed Stirrups $\boxed{6 \phi 8 \backslash m'}$ 2 branches.

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* **Longitudinal Bars.**

$$S_t = \frac{1000}{6} = 166.66\ mm$$

$$A_{sl} = \frac{A_{str} * P_h}{S_t}\left(\frac{F_{y\,str.}}{F_{y\,L.b.}}\right) = \frac{(50.3 * 1780)}{166.66}\left(\frac{240}{360}\right) = 358.15\ mm^2$$

$$\therefore \frac{A_{sl}}{4} = \frac{358.15}{4} = 89.53\ mm^2$$

$$A_{s\,-ve} = A_s + \frac{A_{sl}}{4} = 1010.5 + 89.53 = 1100.03\ mm^2 \qquad 6 \phi 16$$

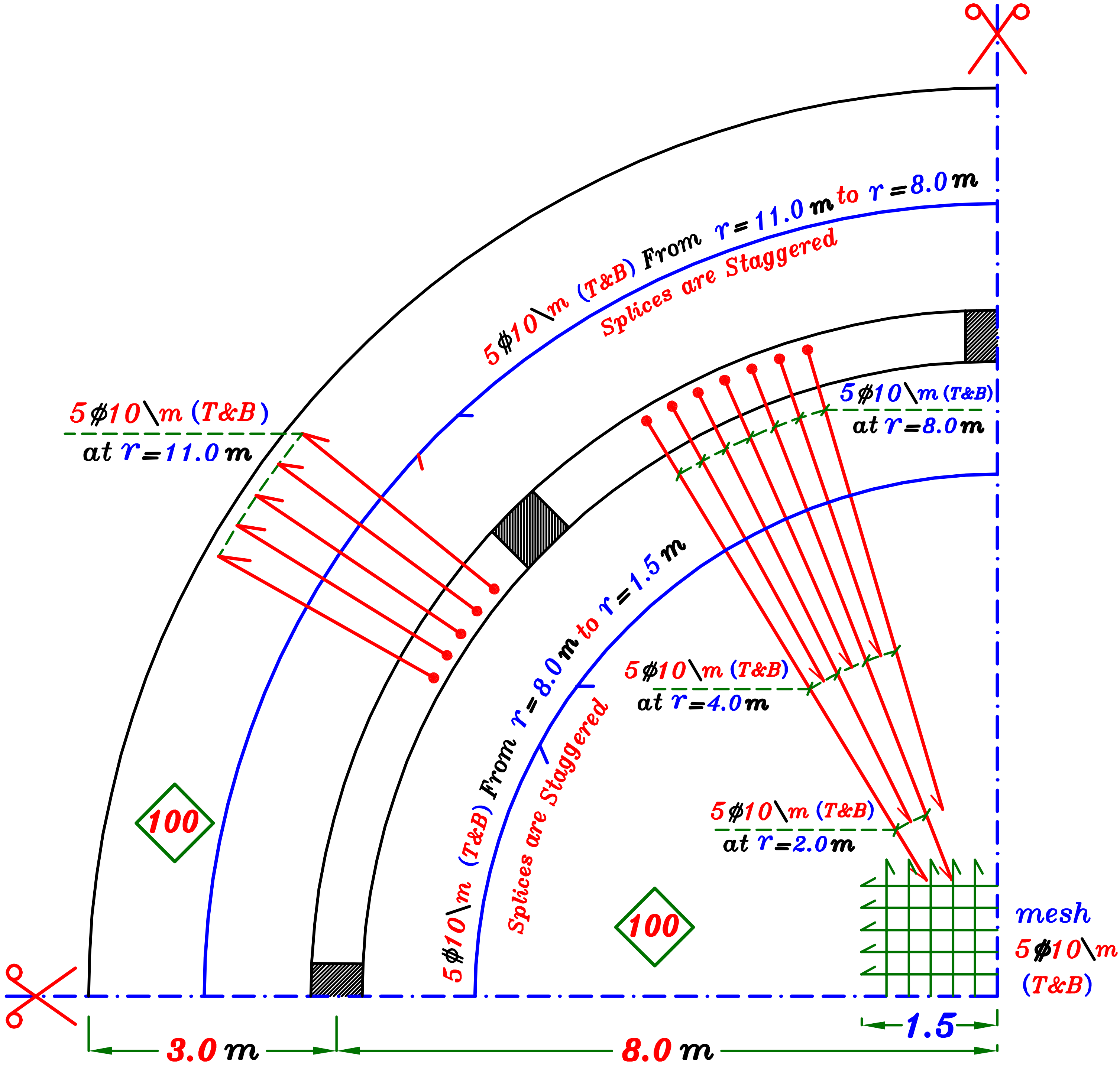
$$\therefore n = \frac{b - 25}{\phi + 25} = \frac{300 - 25}{16 + 25} = 6.70 = 6.0$$

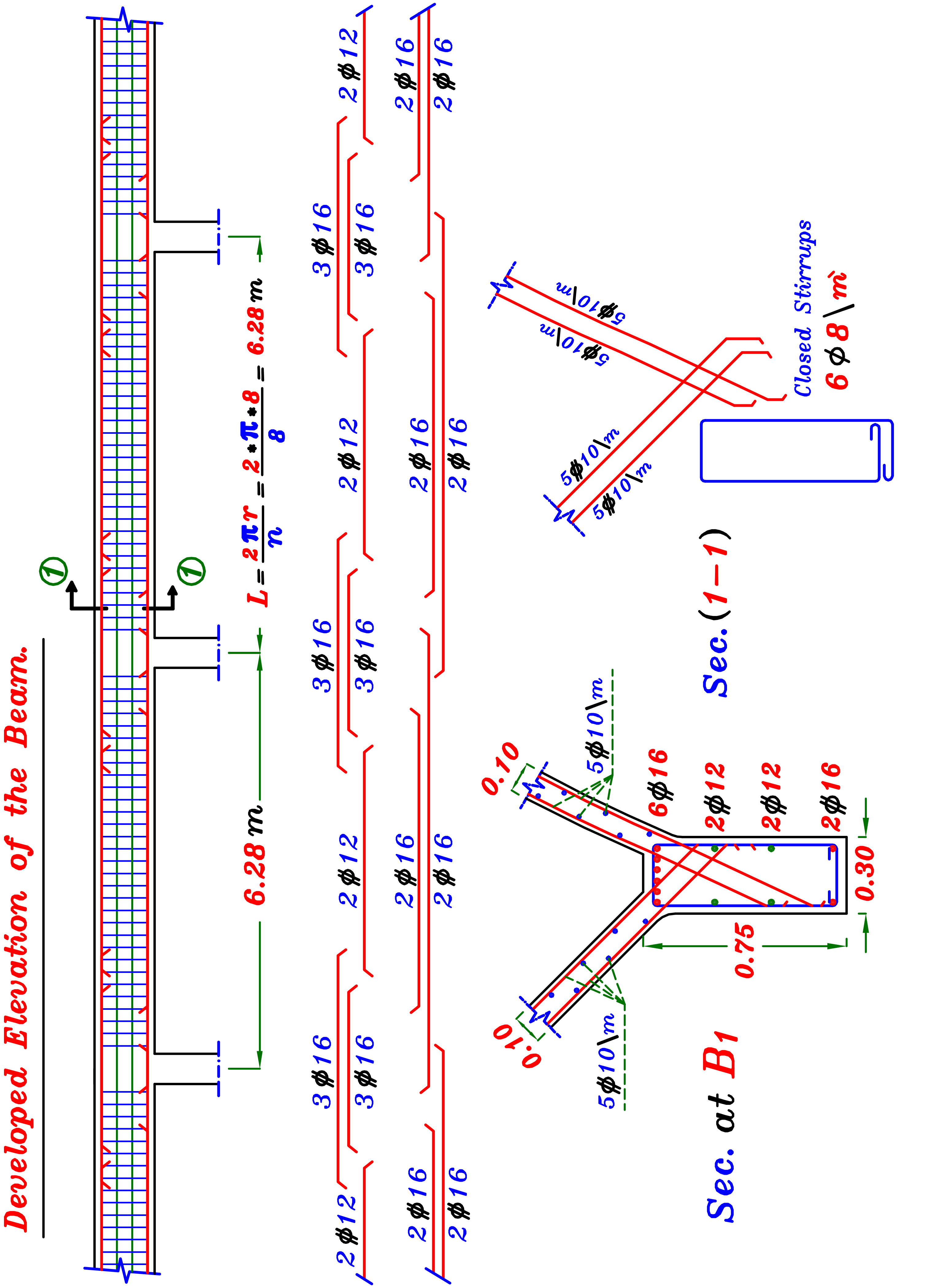
$$A_{s\,+ve} = A_s + \frac{A_{sl}}{4} = 651.8 + 89.53 = 741.33\ mm^2 \qquad 4 \phi 16$$

$$\text{Stirrup Hangers} = \frac{A_s}{10} + \frac{A_{sl}}{4} = \frac{651.8}{10} + 89.53 = 154.71\ mm^2$$

$$2 \phi 12$$

Details of RFT.





Developed Elevation of the Beam.
6.28 m
L = 2πr / n = 2 * π * 8 / 8 = 6.28 m
1
1
2ϕ12
3ϕ16
3ϕ16
2ϕ16
2ϕ16
2ϕ12
Sec. at B1
0.10
0.10
5ϕ10\m
5ϕ10\m
6ϕ16
2ϕ12
2ϕ12
2ϕ16
0.30
0.75
Sec. (1−1)
5ϕ10\m
Closed Stirrups
6ϕ8\m`

Example.

For the shown surface of revolution, It is required to:

1- Calculate the internal Forces at the critical sections.

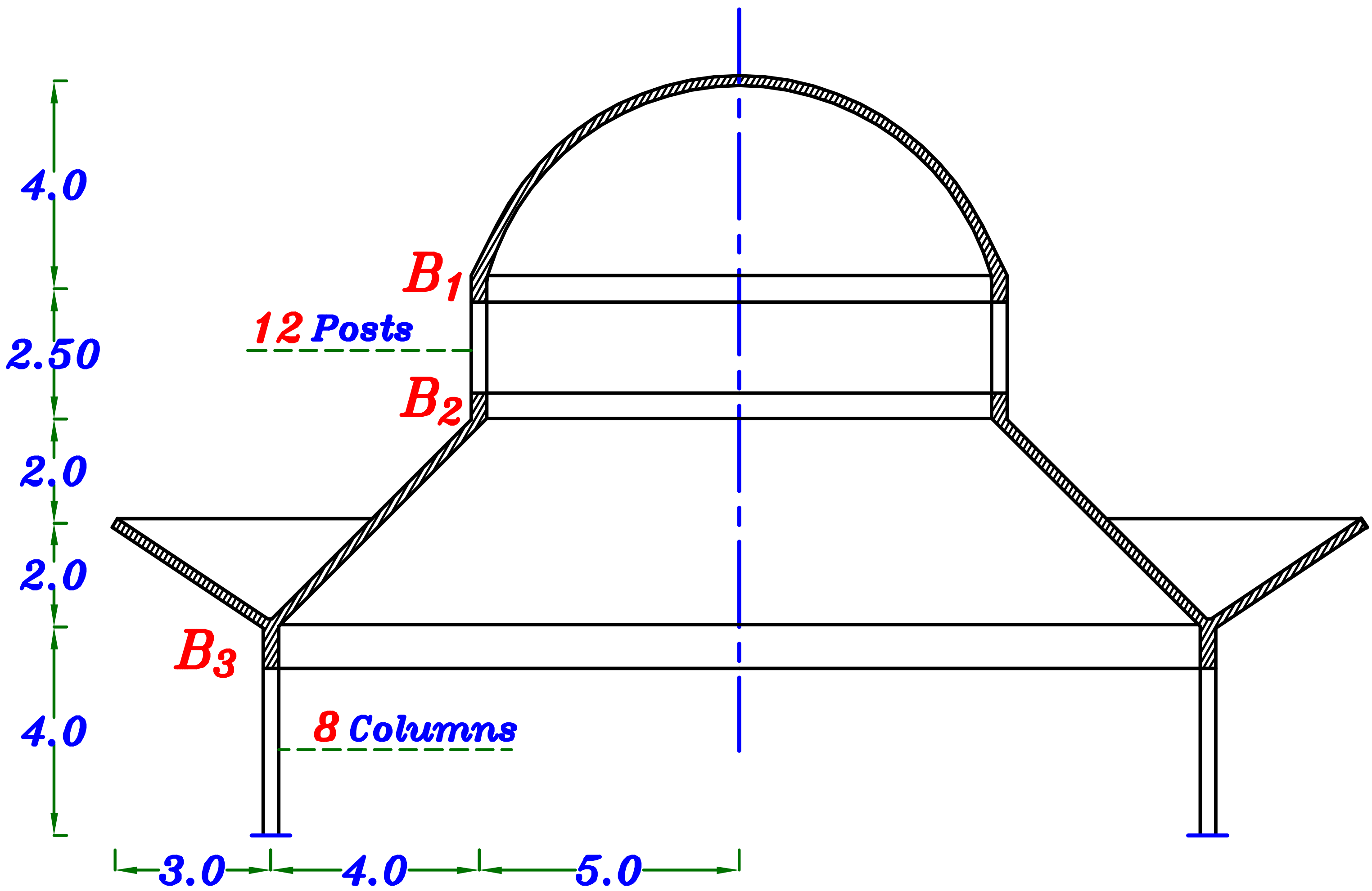
2- Design the surface of revolution and draw details of RFT. in plan and cross sections.

3- Design the supporting beams B_1, B_2 & B_3

Given:

$F.C. = 1.0\ kN/m^2$, $L.L. = 0.50\ kN/m^2$ (H.P.)

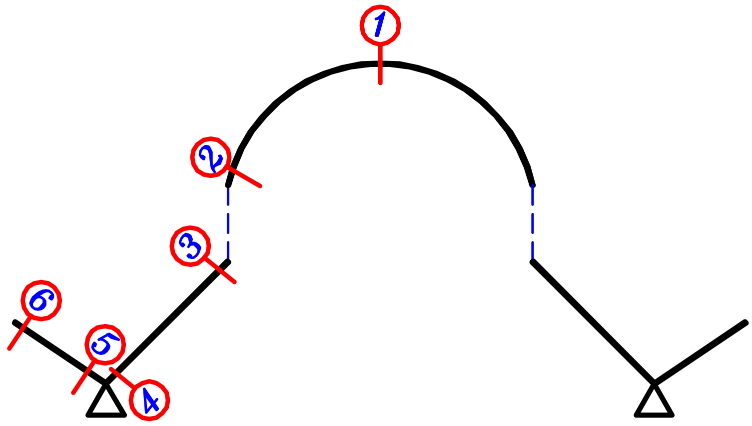
$F_{cu} = 25\ N/mm^2$, st. 360/520



Solution.

Choose $t_s = 100\ mm \longrightarrow 140\ mm$

Take $\boxed{t_s = 100\ mm}$

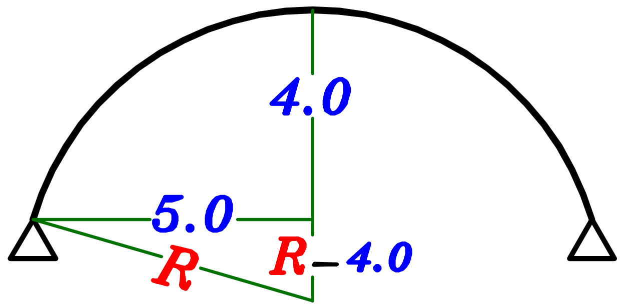


Loads.

$$g_s = t_s\, \gamma_c + F.C. = 0.10 * 25 + 1.0 = 3.5\ kN/m^2$$

$$p_s = 0.5\ kN/m^2$$

For the Dome.



$$R^2 = 5.0^2 + (R - 4.0)^2$$

$$\cancel{R^2} = 25 + \cancel{R^2} - 8.0\,R + 16.0$$

$$8.0\ R = 41.0 \longrightarrow \boxed{R = 5.125\,m}$$

Sec. 1 Dome Vertex $\phi = Zero$

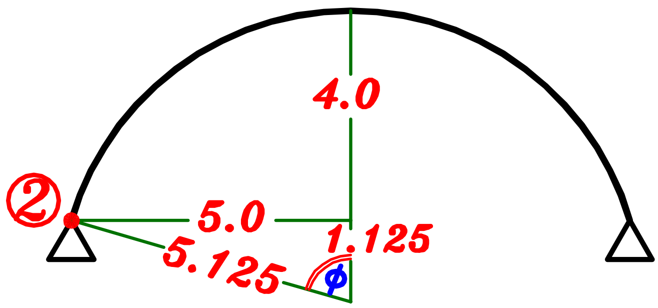
$$Z = g\ Cos\,\phi + p\ Cos^2\phi$$

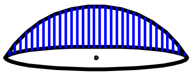
$$= 3.5 * Cos\ 0.0 + 0.5 * Cos^2 0.0 = +4.0\ kN/m^2$$

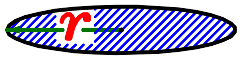
$$(T_1)_1 = (T_2)_1 = \frac{R\,Z}{2} = \frac{5.125 * 4.0}{2} = +\ 10.25\ kN/m\ \ Comp.$$

Sec. 2

$$Sin\,\phi = \frac{5.0}{5.125} \longrightarrow \boxed{\phi = 77.32^\circ}$$



$S.A. = 2\pi * R * h$  $= 2\pi * 5.125 * 4.0 = 128.80\ m^2$

$\text{Projected area} = \pi * r^2$  $= \pi * 5.0^2 = 78.54\ m^2$

$W_\phi = g * S.A. + p * \text{Projected area}$

$= 3.5 * 128.80 + 0.5 * 78.54 = +490.07\ kN$

$$(T_1)_2 = \frac{W_\phi}{2\pi r \ \sin\phi} = \frac{+490.07}{2\pi * 5.0 * \sin 77.32^\circ} = +\ 15.99\ kN/m\ \text{Comp.}$$

$R_1 = R_2 = R = 5.125\ m$

$Z = g \cos\phi + p \cos^2\phi$

$= 3.5 * \cos 77.32 + 0.5 * \cos^2 77.32 = +0.792\ kN/m^2$

$\because\ T_1 + T_2 = Z * R \qquad \therefore\ +15.99 + T_2 = 0.792 * 5.125$

$\therefore\ (T_2)_2 = -\ 11.93\ kN/m\ \text{Ten.}$

For beams B_1 & B_2 $\qquad L = \dfrac{2\pi r}{n} = \dfrac{2 * \pi * 5}{12} = 2.61\ m$

$t = \dfrac{L}{12} + 0.2\,m = \dfrac{2.61}{12} + 0.2 = 0.41 = 0.45\ m$

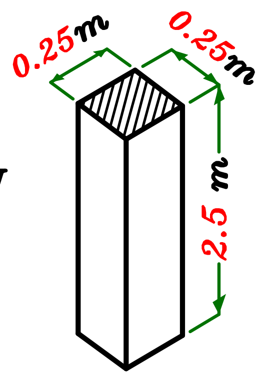
Take B_1 & B_2 $(250 * 450)$

$o.w._{(B_1 \& B_2)} = b * t * \gamma_c = 0.25 * 0.45 * 25 = 2.81\ kN/m$

$T.W. = \text{Total Weight}_{(B_1 \& B_2)} = o.w. * 2\pi r = 2.81 * 2\pi * 5.0 = 88.27\ kN$

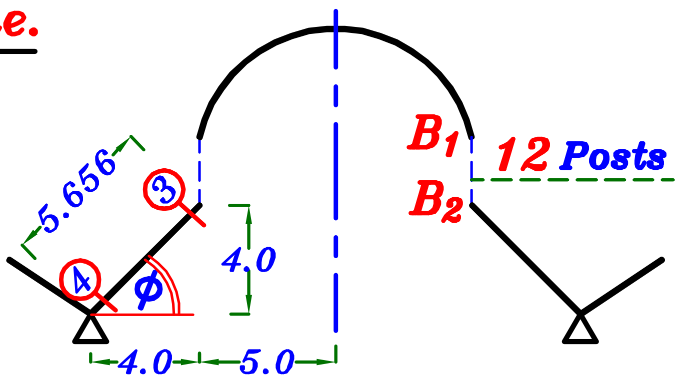
Take Post $(0.25 * 0.25 * 2.50)$

$o.w._{(Post)} = 0.25 * 0.25 * 2.50 * 25 = 3.90\ kN$



For the Cone under the Dome.

$$\tan\phi = \frac{4.0}{4.0} \longrightarrow \boxed{\phi = 45.0^\circ}$$



Sec. ③ $\quad r = 5.0\ m$

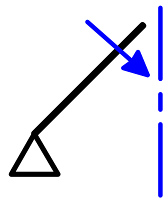
$$W_\phi = W_{\phi\,(Sec.2)} + T.W._{(B_1)} + T.W._{(B_2)} + n * o.w._{(Post)}$$

$$W_\phi = 490.07 + 88.27 + 88.27 + 12 * 3.90 = +713.41\ kN$$

$$(T_1)_3 = \frac{W_\phi}{2\pi r\ \sin\phi} = \frac{+713.41}{2\pi * 5.0 * \sin 45^\circ} = +\ 32.11\ kN/m\ \text{Comp.}$$

$$Z = g\cos\phi + p\cos^2\phi = 3.5 * \cos 45 + 0.5 * \cos^2 45 = +2.725\ kN/m^2$$

$$\boxed{\text{اشاره } Z \text{ (+Ve) لان اتجاهها داخل الى المحور}}$$

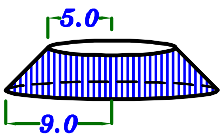


$$R_2 = \frac{r}{\sin\phi} = \frac{5.0}{\sin 45^\circ} = 7.071\ m$$

$$\because\ (T_2)_3 = Z * R_2 = +2.725 * 7.071 = +\ 19.27\ kN/m\ \text{Comp.}$$

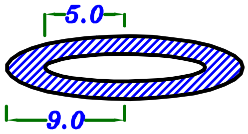
Sec. ④ $\quad r = 9.0\ m$

$$S.A. = \pi * L\,(a+b)$$



$$= \pi * 5.656 * (9.0 + 5.0) = 248.76\ m^2$$

$$\text{Projected area} = \pi * (r_1^2 - r_2^2)$$



$$= \pi * (9.0^2 - 5.0^2) = 175.93\ m^2$$

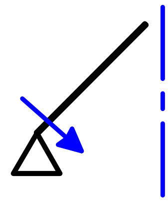
$$W_\phi = W_{\phi\,(Sec.3)} + g * S.A. + p * \text{Projected area}$$

$$= 713.41 + 3.5 * 248.76 + 0.5 * 175.93 = +1672.03\ kN$$

$$(T_1)_4 = \frac{W_\phi}{2\pi r\ \sin\phi} = \frac{+1672.03}{2\pi * 9.0 * \sin 45^\circ} = +\ 41.81\ kN/m\ \text{Comp.}$$

$$Z = g\ Cos\ \phi + p\ Cos^2\phi = 3.5 * Cos\ 45 + 0.5 * Cos^2 45 = +2.725\ kN/m^2$$

اشاره Z $(+Ve)$ لان اتجاهها داخل الى المحور

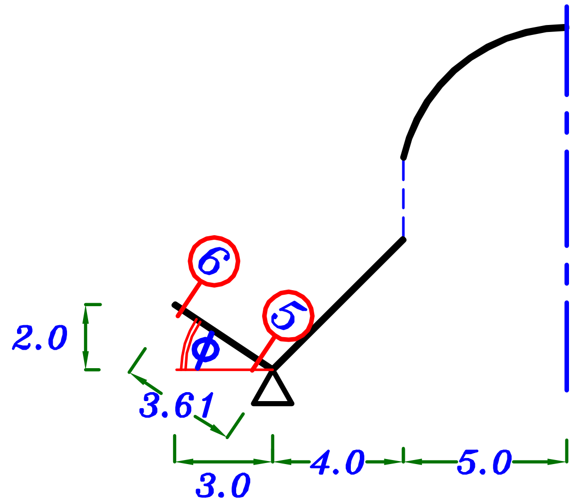


$$R_2 = \frac{r}{Sin\phi} = \frac{9.0}{Sin\ 45^\circ} = 12.727\ m$$

$$\because\ (T_2)_4 = Z * R_2 = +2.725 * 12.727 = +34.68\ kN/m\ \ Comp.$$

For the outer Cone.

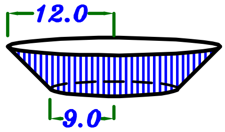
$$tan\ \phi = \frac{2.0}{3.0} \longrightarrow \boxed{\phi = 33.69^\circ}$$



Sec. 5

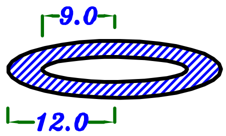
$$r = 9.0\ m$$

$$S.A. = \pi * L\ (a+b)$$



$$= \pi * 3.61 * (12.0 + 9.0) = 238.16\ m^2$$

$$Projected\ \ area = \pi * (r_1^2 - r_2^2)$$



$$= \pi * (12.0^2 - 9.0^2) = 197.92\ m^2$$

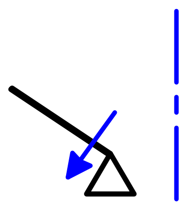
$$W_\phi = g * S.A. + p * Projected\ \ area$$

$$= 3.5 * 238.16 + 0.5 * 197.92 = +932.52\ kN$$

$$(T_1)_5 = \frac{W_\phi}{2\pi r\ \ Sin\phi} = \frac{+932.52}{2\pi * 9.0 * Sin\ 33.69} = +29.728\ kN/m\ \ Comp.$$

$$Z = g\ Cos\ \phi + p\ Cos^2\phi = 3.5 * Cos\ 33.69 + 0.5 * Cos^2 33.69 = -3.26\ kN/m^2$$

اشاره Z $(-Ve)$ لان اتجاهها خارج من المحور



$$R_2 = \frac{r}{Sin\phi} = \frac{9.0}{Sin\ 33.69} = 16.22\ m$$

$$\because\ (T_2)_5 = Z * R_2 = -3.26 * 16.22 = -52.87\ kN/m\ \ Ten.$$

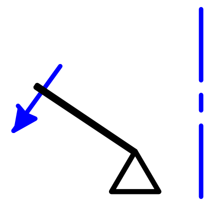
Sec. ⑥

$r = 12.0\ m$

$W_\phi = Zero \longrightarrow (T_1)_6 = Zero$

$Z = g\ \cos\phi + p\ \cos^2\phi = 3.5 * \cos 33.69 + 0.5 * \cos^2 33.69 = -3.26\ kN/m^2$

$R_2 = \dfrac{r}{\sin\phi} = \dfrac{12.0}{\sin 33.69^\circ} = 21.63\ m$



$(T_2)_6 = Z * R_2 = -3.26 * 21.63 = -70.51\ kN/m$ Ten.

Design of Sections.

For the Dome. Sec. ① & Sec. ②

$(T_{max}) = 15.99\ kN/m$ Comp.

$\text{Actual Stress} = \dfrac{T_{max}}{A_c} = \dfrac{T_{max}}{1000 * t_s} = \dfrac{15.99 * 10^3}{1000 * 100} = 0.16\ N/mm^2$

$F_{cu} = 25\ N/mm^2 \longrightarrow F_{co} = 6.0\ N/mm^2$

$\text{Allawable Stress} = \dfrac{F_{co}}{2} = \dfrac{6.0}{2} = 3.0\ N/mm^2$

Actual Stress < Allawable Stress $\longrightarrow$ $t_s = 100$ mm is o.k.

To Get T_1 RFT. $\longrightarrow$ No Tension $\xrightarrow{\text{use min. RFT.}}$ $5 \phi 10 \backslash m'$ each Side

To Get T_2 RFT. $\longrightarrow$ max. Tension $T_2 = 11.93\ kN/m$

$As_{(T_2)} = \dfrac{T_{2\,(U.L.)}}{F_y \backslash \gamma_s} = \dfrac{1.5 * 11.93 * 10^3}{360 \backslash 1.15} = 57.16\ mm^2/m$

$As_{(T_2)} \backslash Side = \dfrac{57.16}{2} = 28.58\ mm^2/m \xrightarrow{\text{use min. RFT.}} 5 \phi 10 \backslash m'$ each Side

For the Cone under the Dome. Sec. 3 & Sec. 4

$(T_{max}) = 41.81$ kN/m Comp.

$$\text{Actual Stress} = \frac{T_{max}}{A_c} = \frac{T_{max}}{1000 * t_s} = \frac{41.81 * 10^3}{1000 * 100} = 0.418 \ N/mm^2$$

$$F_{cu} = 25 \ N/mm^2 \longrightarrow F_{co} = 6.0 \ N/mm^2$$

$$\text{Allawable Stress} = \frac{F_{co}}{2} = \frac{6.0}{2} = 3.0 \ N/mm^2$$

Actual Stress $<$ Allawable Stress $\longrightarrow$ $t_s = 100$ mm is o.k.

To Get T_1 RFT. $\longrightarrow$ No Tension $\xrightarrow{\text{use min. RFT.}}$ $5 \phi 10 \backslash m'$ each Side

To Get T_2 RFT. $\longrightarrow$ No Tension $\xrightarrow{\text{use min. RFT.}}$ $5 \phi 10 \backslash m'$ each Side

For the outer Cone. Sec. 5 & Sec. 6

$(T_{max}) = 29.728$ kN/m Comp.

$$\text{Actual Stress} = \frac{T_{max}}{A_c} = \frac{T_{max}}{1000 * t_s} = \frac{29.728 * 10^3}{1000 * 100} = 0.297 \ N/mm^2$$

$$\text{Allawable Stress} = \frac{F_{co}}{2} = \frac{6.0}{2} = 3.0 \ N/mm^2$$

Actual Stress $<$ Allawable Stress $\longrightarrow$ $t_s = 100$ mm is o.k.

To Get T_1 RFT. $\longrightarrow$ No Tension $\xrightarrow{\text{use min. RFT.}}$ $5 \phi 10 \backslash m'$ each Side

To Get T_2 RFT. $\longrightarrow$ max. Tension $T_2 = 70.51$ kN/m

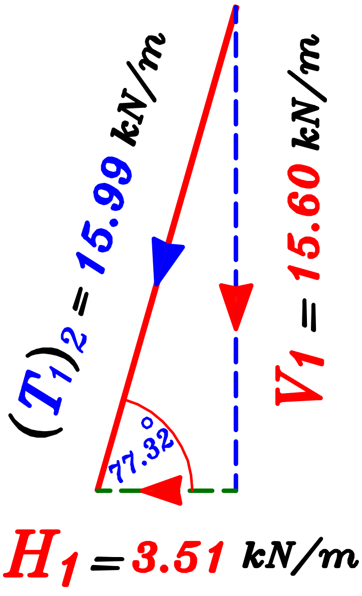
$$A_{s(T_2)} = \frac{T_{2\,(U.L.)}}{F_y \backslash \gamma_s} = \frac{1.5 * 70.51 * 10^3}{360 \backslash 1.15} = 337.86 \ mm^2/m$$

$$A_{s(T_2)} \backslash Side = \frac{337.86}{2} = 168.93 \ mm^2/m \xrightarrow{\text{use min. RFT.}} 5 \phi 10 \backslash m' \text{ each Side}$$

Design of Beam B_1

$w = o.w. + V_1 = 2.81 + 15.60 = 18.41$ kN/m

$H = H_1 = 3.51$ kN/m للخارج



Tension Force on Beam $= H * r$

$= 3.51 * 5.0 = 17.55$ kN

$\because$ n = Number of supports = 12

$\therefore$ We can neglect M_t

$$L = \frac{2\pi r}{n} = \frac{2 * \pi * 5}{12} = 2.61 \text{ m}$$

$$\therefore \text{ max. } M_{-Ve} = \frac{wL^2}{12} = \frac{18.41 * 2.61^2}{12} = 10.45 \text{ kN.m}$$

$$\text{max. } M_{+Ve} = \frac{wL^2}{24} = \frac{18.41 * 2.61^2}{24} = 5.225 \text{ kN.m}$$

$$\text{max. } Q = \frac{wL}{2} = \frac{18.41 * 2.61}{2} = 24.02 \text{ kN}$$

Design beam B_1 on M & T

$b = 250$ mm , $t = 450$ mm

Sec. of max. $-Ve$ B.M.

$M = 10.45 * 1.5 = 15.67$ kN.m. , $T = 17.55 * 1.5 = 26.32$ kN

$$e = \frac{M}{T} = \frac{15.67}{26.32} = 0.59 \text{ m}$$

$$\therefore \frac{e}{t} = \frac{0.59}{0.45} = 1.31 > 0.5 \xrightarrow{\text{Use}} e_s$$

$$e_s = e - \frac{t}{2} + c = 0.59 - \frac{0.45}{2} + 0.05 = 0.415 \text{ m}$$

$$M_s = T * e_s = 26.32 * 0.415 = 10.92 \text{ kN.m}$$

$$\therefore\ d = C_1\sqrt{\frac{M_s}{F_{cu}\, b}} \quad \therefore\ 400 = C_1\sqrt{\frac{10.92 * 10^6}{25 * 250}} \rightarrow C_1 = 9.57 \rightarrow J = 0.826$$

$$\therefore\ A_s = \frac{M_s}{J\, F_y\, d} + \frac{T_{U.L.}}{(F_y \backslash \gamma_s)} = \frac{10.92 * 10^6}{0.826 * 360 * 400} + \frac{26.32 * 10^3}{(360 \backslash 1.15)}$$

$$= 175.88\ mm^2$$

Check $A_{s_{min.}}$ $\quad A_{s_{req.}} = 175.88\ mm^2$

$$\mu_{min.}\, b\, d = \left(0.225 * \frac{\sqrt{F_{cu}}}{F_y}\right) b\, d = \left(0.225 * \frac{\sqrt{25}}{360}\right) 250 * 400 = 312.5\ mm^2$$

$$\therefore\ \mu_{min.}\, b\, d > A_{s_{req.}} \xrightarrow{Use} A_{s_{min.}}$$

$$A_{s_{min.}} = 0.225 * \frac{\sqrt{F_{cu}}}{F_y}\, b\, d = \left(0.225 * \frac{\sqrt{25}}{360}\right) 250 * 400 = 312.5$$

$$1.3\ A_{s_{req.}} = 1.3 * 175.88 = 228.6$$

الأقل $= 228.6$

st. 360/520 $\quad \frac{0.15}{100}\, b\, d = \frac{0.15}{100} * 250 * 400 = 150\ mm^2$

الأكبر $= 228.6\ mm^2$

$3\phi 12$

Sec. of max. + Ve B.M.

Take $A_s = A_{s_{min.}} = 3\phi 12$

Check Shear.

- Allowable shear stress.

$$q_{cu} = 0.24\sqrt{\frac{F_{cu}}{\gamma_c}} = 0.24\sqrt{\frac{25}{1.5}} = 0.98\ N\backslash mm^2$$

$$q_{max.} = 0.70\sqrt{\frac{F_{cu}}{\gamma_c}} = 0.70\sqrt{\frac{25}{1.5}} = 2.85\ N\backslash mm^2$$

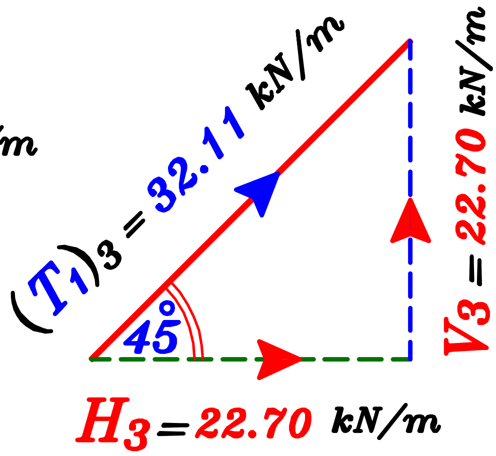
Actual shear stress.

$$q_U = \frac{Q_{max}}{b\, d} = \frac{1.5 * 24.02 * 10^3}{250 * 400} = 0.360\ N\backslash mm^2$$

$\therefore\ q_U < q_{min} \quad \therefore$ Use min. Stirrups $\boxed{5\phi 8 \backslash m'}$

Design of Beam B_2

$$w = V_3 - o.w. = 22.70\uparrow - 2.81\downarrow = 19.89\ kN/m$$



V_3 اتجاهها لاعلى لكن ال $o.w.$ اتجاهها لاسفل

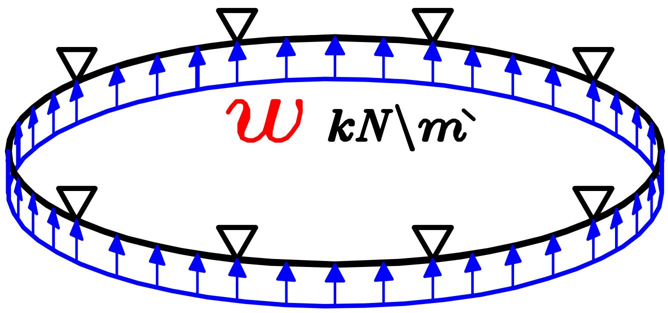
$$H = H_3 = 22.70\ kN/m$$ للداخل

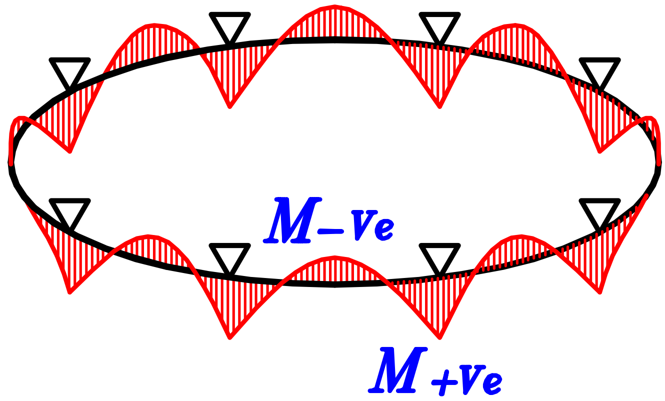
Compression Force on Beam $= H * r$

$$= 22.70 * 5.0 = 113.5\ kN$$

لان الحمل المنتظم على الكمره اتجاهه من اسفل الى اعلى اذا سينعكس اتجاه العزم

و ستنعكس قيمه كلا من $(max.\ M_{-Ve})$ و $(max.\ M_{+Ve})$





$\because$ n = Number of supports = 12

$\therefore$ We can neglect M_t

$$L = \frac{2\pi r}{n} = \frac{2 * \pi * 5}{12} = 2.61\ m$$

$$\therefore\ max.\ M_{-Ve} = \frac{wL^2}{24} = \frac{19.89 * 2.61^2}{24} = 5.64\ kN.m$$

$$max.\ M_{+Ve} = \frac{wL^2}{12} = \frac{19.89 * 2.61^2}{12} = 11.29\ kN.m$$

$$max.\ Q = \frac{wL}{2} = \frac{19.89 * 2.61}{2} = 25.95\ kN$$

Design beam B2 on M & P

$b = 250\ mm$, $t = 450\ mm$

Sec. of max. +Ve B.M.

$M = 11.29 * 1.5 = 16.935\ kN.m.$, $P = 113.5 * 1.5 = 170.25\ kN$

Check $\dfrac{P}{F_{cu}\, b\, t} = \dfrac{170.25 * 10^{3}}{25 * 250 * 450} = 0.06 > 0.04$ (Don't neglect P)

$\therefore$ Design the Sec. on both N.F. & B.M.

$$e = \frac{M}{P} = \frac{16.935}{170.25} = 0.099\ m$$

$$\frac{e}{t} = \frac{0.099}{0.45} = 0.22 < 0.50 \longrightarrow \text{Compression Failure} \xrightarrow{use} I.D.$$

$$\zeta = \frac{450 - 100}{450} = 0.77 = 0.70 \xrightarrow{use} \text{ECCS Design Aids Page } 4\text{–}25$$

$$\left.\begin{aligned} \frac{P}{F_{cu}\, b\, t} &= \frac{170.25 * 10^{3}}{25 * 250 * 450} = 0.06 \\ \frac{M}{F_{cu}\, b\, t^{2}} &= \frac{16.935 * 10^{6}}{25 * 250 * 450^{2}} = 0.013 \end{aligned}\right\} \rho < 1.0 \xrightarrow{Take} \rho = 1.0$$

$$\mu = \rho * F_{cu} * 10^{-4} = 1.0 * 25 * 10^{-4} = 2.50 * 10^{-3}$$

$$A_s = A_s` = \mu * b * t = 2.50 * 10^{-3} * 250 * 450 = 281.25\ mm^2$$

$$A_{s\,Total} = A_s + A_s` = 2 * 281.25 = 562.5\ mm^2$$

Check $A_{s\,min.} = \dfrac{0.8}{100} * b * t = \dfrac{0.8}{100} * 250 * 450 = 900\ mm^2$

$\therefore A_{s\,Total} < A_{s\,min.}$ $\therefore$ Take $A_{s\,Total} = A_{s\,min.}$

$$\therefore A_s = A_s` = \frac{A_{s\,min.}}{2} = \frac{900}{2} = 450.0\ mm^2 \quad 4\phi12$$

Sec. of max. $-$ Ve B.M.

$$M = 5.64 * 1.5 = 8.46 \text{ kN.m.} \quad , \quad P = 113.5 * 1.5 = 170.25 \text{ kN}$$

$$\therefore \text{ Take } A_s = A_s` = \frac{A_{s\,min.}}{2} = \frac{900}{2} = 450.0 \text{ mm}^2 \quad 4\phi12$$

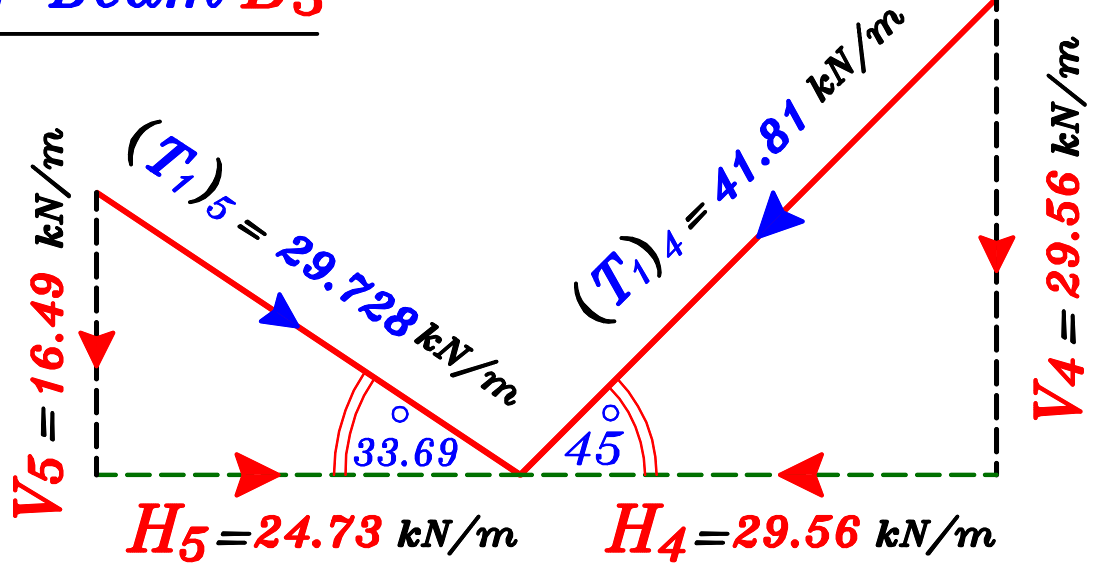
Check Shear.

$$q_U = \frac{Q_{max}}{b\,d} = \frac{1.5 * 25.95 * 10^3}{250 * 400} = 0.39 \text{ N}\backslash\text{mm}^2$$

$$q_{cu} = 0.24\sqrt{\frac{F_{cu}}{\gamma_c}} = 0.24\sqrt{\frac{25}{1.5}} = 0.98 \text{ N}\backslash\text{mm}^2$$

$$\therefore q_U < q_{min} \qquad \therefore \text{ Use min. Stirrups } \boxed{5\phi 8\backslash m}$$

Design of Beam B_3



$$L = \frac{2\pi r}{n} = \frac{2*\pi*9}{8} = 7.07\ m$$

$$t = \frac{L}{12} + 0.2\ m = \frac{7.07}{12} + 0.2 = 0.79 = 0.80\ m$$

Take B_1 (300*800)

$$o.w._{(beam)} = b*t*\gamma_c = 0.30*0.80*25 = 6.0\ kN/m$$

$$w = o.w. + V_4 + V_5 = 6.0 + 29.56 + 16.49 = 52.05\ kN/m$$

$$H = H_4 - H_5 = 29.56 - 24.73 = 4.83\ kN/m$$ للخارج

Tension Force on Beam $= H * r = 4.83 * 9.0 = 43.47$ kN

From Tables

$n = 8.0$

No. of supports	Load on each support	Max. Shearing Force	Max. Bending Moment at C.L. of Span	Max. Bending Moment Over C.L. of Column	Max. Torsional Moment	Central angle
n	R	$Q_{max.}$	M +Ve	M −Ve	$M_{t\,max.}$	θ
4	P/4	P/8	0.0176 Pr	− 0.0322 Pr	0.0053 Pr	19° 21`
6	P/6	P/12	0.0075 Pr	− 0.0148 Pr	0.0015 Pr	12° 44`
8	**P/8**	**P/16**	**0.0042 Pr**	**− 0.0083 Pr**	**0.0006 Pr**	**9° 33`**
10	P/10	P/20	0.0032 Pr	− 0.0052 Pr	0.0004 Pr	7° 36`
12	P/12	P/24	0.0019 Pr	− 0.0037 Pr	0.0002 Pr	6° 21`

$$P = w * 2\pi r = 52.05 * 2\pi * 9.0 = 2943.36 \ kN$$

$$max.\ M_{+Ve} = 0.0042\ Pr = 0.0042 * 2943.36 * 9.0 = 111.26 \ kN.m$$

$$max.\ M_{-Ve} = 0.0083\ Pr = 0.0083 * 2943.36 * 9.0 = 219.87 \ kN.m$$

$$max.\ M_{t} = 0.0006\ Pr = 0.0006 * 2943.36 * 9.0 = 15.89 \ kN.m$$

$$Q_{max.} = \frac{P}{16} = \frac{2943.36}{16} = 183.96 \ kN$$

Central angle $\theta = 9^\circ 33' = 9.55^\circ$

$$X = r * \theta * \frac{\pi}{180} = 9.0 * 9.55 * \frac{\pi}{180} = 1.50 \ m$$

$$Q_{cor.} = Q_{max} - w * X = 183.96 - 52.05 * 1.50 = 105.88 \ kN$$

Design beam B3 on M & T

$b = 300$ mm , $t = 800$ mm

Sec. of max. $-Ve$ B.M.

$M = 219.87 * 1.5 = 329.8$ kN.m. , $T = 43.47 * 1.5 = 65.20$ kN

$$e = \frac{M}{T} = \frac{329.8}{65.20} = 5.05 \ m$$

$$\therefore \frac{e}{t} = \frac{5.05}{0.80} = 6.31 > 0.5 \xrightarrow{Use} e_s$$

$$e_s = e - \frac{t}{2} + c = 5.05 - \frac{0.80}{2} + 0.05 = 4.70 \ m$$

$$M_s = T * e_s = 65.20 * 4.70 = 306.44 \ kN.m$$

$$\therefore d = c_1 \sqrt{\frac{M_s}{F_{cu}\, b}} \quad \therefore 750 = c_1 \sqrt{\frac{306.44 * 10^6}{25 * 300}} \rightarrow c_1 = 3.71 \rightarrow J = 0.791$$

$$\therefore A_s = \frac{M_s}{J\,F_y\,d} + \frac{T_{U.L.}}{(F_y \backslash \gamma_s)}$$

$$= \frac{306.44 * 10^6}{0.791 * 360 * 750} + \frac{65.20 * 10^3}{(360 \backslash 1.15)} = 1643.1 \ mm^2$$

Check $A_{s_{min.}}$ $\qquad A_{s_{req.}} = 1643.1 \ mm^2$

$$\mu_{min.}\,b\,d = \left(0.225 * \frac{\sqrt{F_{cu}}}{F_y}\right) b\,d = \left(0.225 * \frac{\sqrt{25}}{360}\right) 300 * 750 = 703.1 \ mm^2$$

$$\therefore A_{s_{req.}} > \mu_{min.}\,b\,d \quad \therefore \text{Take } A_s = A_{s_{req.}} = 1643.1 \ mm^2$$

Sec. of max. +Ve B.M.

$$M = 111.26 * 1.5 = 166.89 \ kN.m. \ , \quad T = 43.47 * 1.5 = 65.20 \ kN$$

$$e = \frac{M}{T} = \frac{166.89}{65.20} = 2.56 \ m$$

$$\therefore \frac{e}{t} = \frac{2.56}{0.80} = 3.20 > 0.5 \xrightarrow{Use} e_s$$

$$e_s = e - \frac{t}{2} + C = 2.56 - \frac{0.80}{2} + 0.05 = 2.21 \ m$$

$$M_s = T * e_s = 65.20 * 2.21 = 144.09 \ kN.m$$

$$\therefore d = C_1 \sqrt{\frac{M_s}{F_{cu}\,b}} \quad \therefore 750 = C_1 \sqrt{\frac{144.09 * 10^6}{25 * 300}} \rightarrow C_1 = 5.41 \rightarrow J = 0.826$$

$$\therefore A_s = \frac{M_s}{J\,F_y\,d} + \frac{T_{U.L.}}{(F_y \backslash \gamma_s)}$$

$$= \frac{144.09 * 10^6}{0.826 * 360 * 750} + \frac{65.20 * 10^3}{(360 \backslash 1.15)} = 854.36 \ mm^2$$

Check $As_{min.}$ $As_{req.} = 854.36\ mm^2$

$$\mu_{min.}\, b\, d = \left(0.225 * \frac{\sqrt{F_{cu}}}{F_y}\right) b\, d = \left(0.225 * \frac{\sqrt{25}}{360}\right) 300 * 750 = 703.1\ mm^2$$

$$\therefore \mu_{min.}\, b\, d > As_{req.} \xrightarrow{Use} As_{min.}$$

$$As_{min.} = 0.225 * \frac{\sqrt{F_{cu}}}{F_y}\, b\, d = \left(0.225 * \frac{\sqrt{25}}{360}\right) 300 * 750 = 703.1$$

$$1.3\, As_{req.} = 1.3 * 854.36 = 1110.6$$

الأقل $= 703.1$

st. 360/520 $\quad \frac{0.15}{100}\, b\, d = \frac{0.15}{100} * 300 * 750 = 337.5\ mm^2$

الأكبر $= 703.1\ mm^2$

Design due to Shear & Torsion. $b = 300\ mm$, $t = 800\ mm$

$$q_u = \frac{Q}{b\, d} = \frac{1.5 * 105.88 * 10^3}{300 * 750} = 0.705\ N/mm^2$$

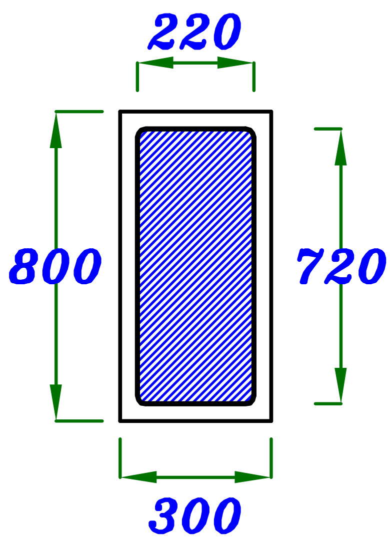
$$A_{oh} = 220 * 720 = 158400\ mm^2$$

$$A_o = 0.85 * A_{oh} = 0.85 * 158400 = 134640\ mm^2$$

$$P_h = 2 * 220 + 2 * 720 = 1880\ mm$$

$$t_e = \frac{A_{oh}}{P_h} = \frac{158400}{1880} = 84.25\ mm$$

$$q_{tu} = \frac{M_{tu}}{2\, A_o\, t_e} = \frac{1.5 * 15.89 * 10^6}{2 * 134640 * 84.25} = 1.05\ N/mm^2$$



$$q_{cu} = (0.24)\sqrt{\frac{25}{1.5}} = 0.98\ N/mm^2$$

$$q_{t\,min} = (0.06)\sqrt{\frac{25}{1.5}} = 0.245\ N/mm^2$$

$$q_{u\,max} = (0.7)\sqrt{\frac{25}{1.5}} = 2.85\ N/mm^2$$

$$\sqrt{q_u^2 + q_{tu}^2} = \sqrt{0.705^2 + 1.05^2} = 1.264\ N/mm^2 < q_u \quad \therefore o.k.$$

$$\boxed{q_u < q_{cu}\ ,\ q_{tu} > q_{t\,min}}$$

$\therefore$ Use RFT. For Torsion only.

* Stirrups.

$$\therefore A_{str} = \frac{M_{tu} \; S_t}{(1.7)\; A_{oh}\; \left(\frac{F_y}{\gamma_s}\right)} \qquad \therefore A_{str} = \frac{(1.5 * 15.89 * 10^6) * S_t}{(1.7)(158400)(240/1.15)}$$

$$\therefore \boxed{S_t = 2.358 * A_{str}}$$

* Take $\phi\, 8 \longrightarrow A_{str} = 50.3\ mm^2$

$$\therefore S_t = 2.358 * A_{str} = 2.358 * 50.3 = 118.61\ mm > 100\ mm \quad \therefore o.k.$$

$$\therefore \text{No. of stirrups} \backslash m' = \frac{1000}{S} = \frac{1000}{118.61} = 8.43 = 9.0$$

$\therefore$ Use Closed Stirrups $\boxed{9 \phi 8 \backslash m'}$ 2 branches.

---

* Longitudinal Bars.

$$S_t = \frac{1000}{9} = 111.11\ mm$$

$$A_{sl} = \frac{A_{str} * P_h}{S_t} \left(\frac{F_{y\,str.}}{F_{y\,L.b.}}\right) = \frac{(50.3 * 1880)}{111.11} \left(\frac{240}{360}\right) = 567.39\ mm^2$$

$$\therefore \frac{A_{sl}}{4} = \frac{567.39}{4} = 141.84\ mm^2$$

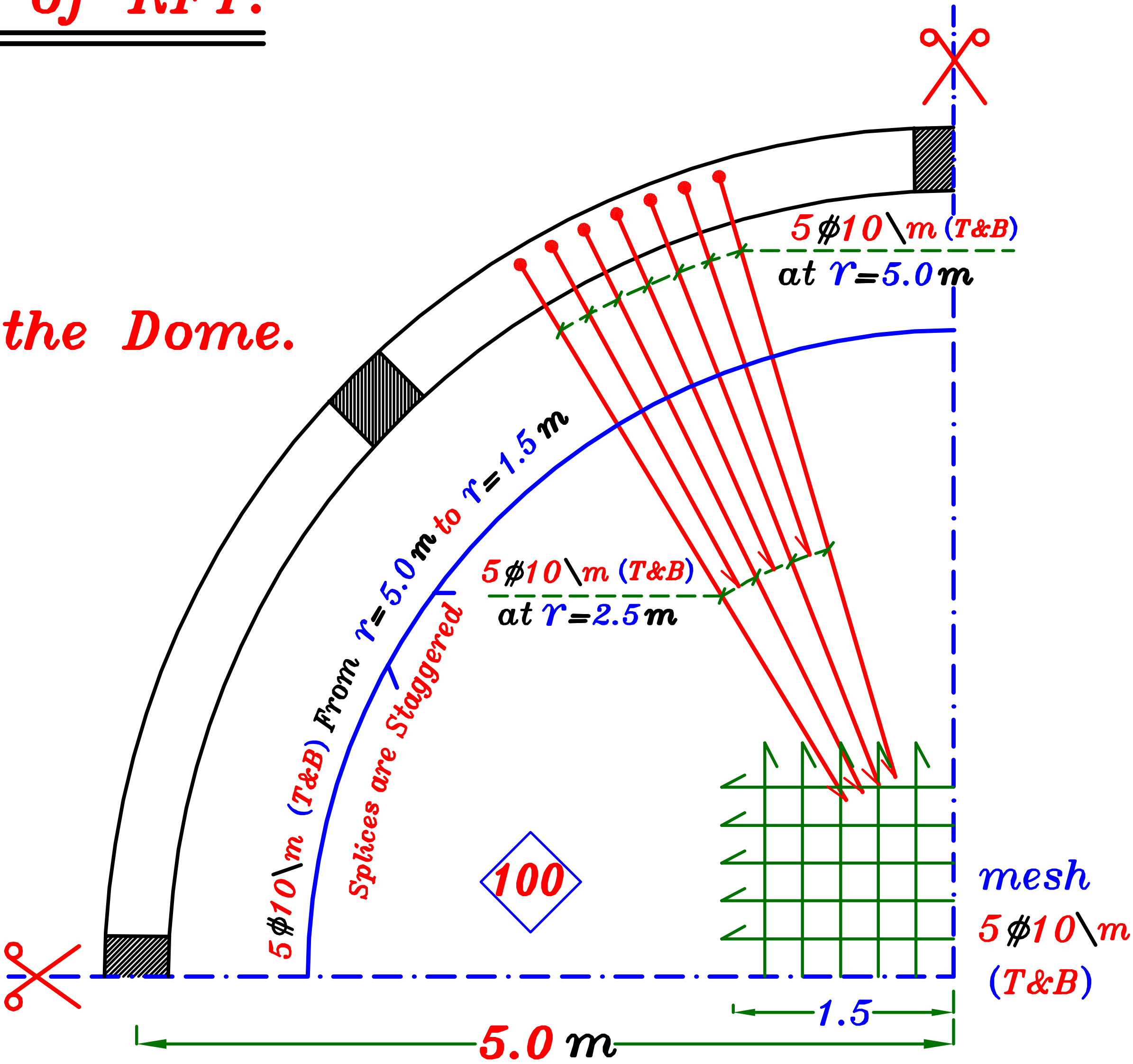
$$A_{s\,-ve} = A_s + \frac{A_{sl}}{4} = 1643.1 + 141.84 = 1784.94\ mm^2 \qquad 9 \phi 16$$

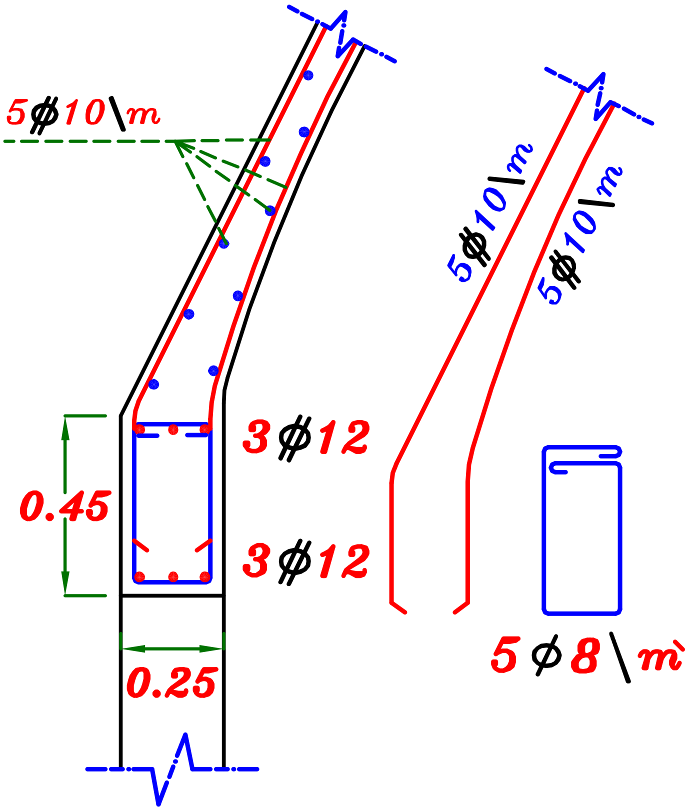
$$\therefore n = \frac{b - 25}{\phi + 25} = \frac{300 - 25}{16 + 25} = 6.70 = 6.0$$

$$A_{s\,+ve} = A_s + \frac{A_{sl}}{4} = 703.1 + 141.84 = 844.94\ mm^2 \qquad 5 \phi 16$$

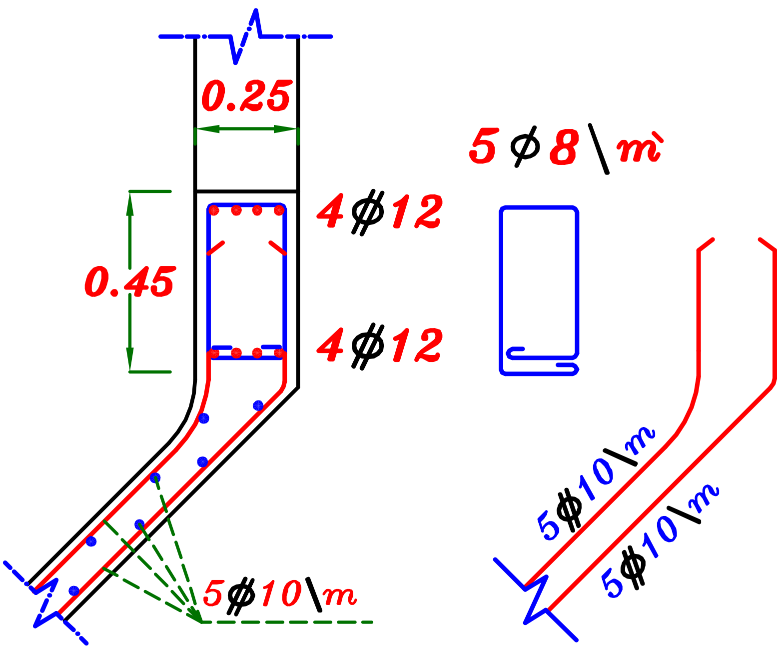
Details of RFT.

Plan of the Dome.



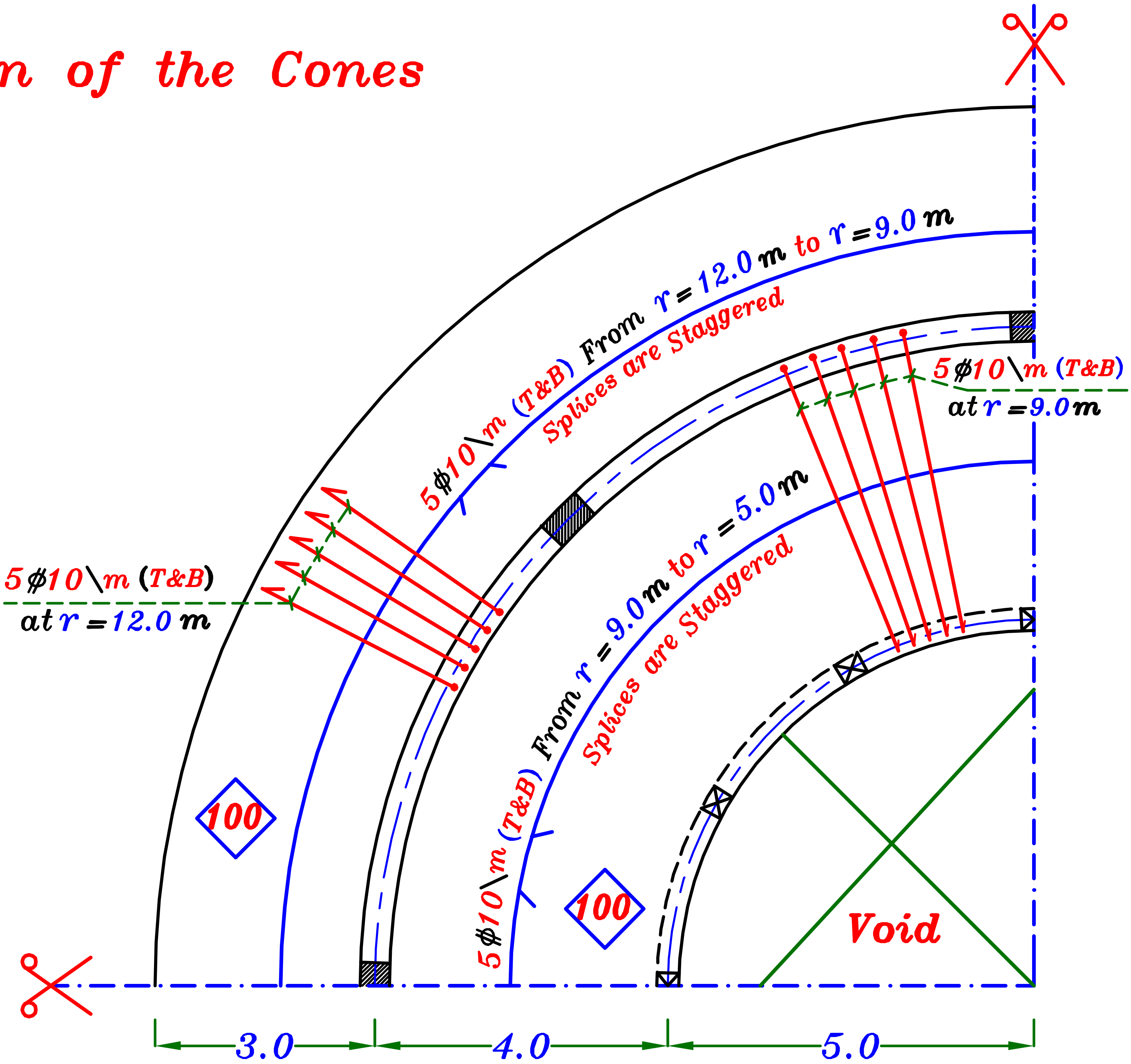


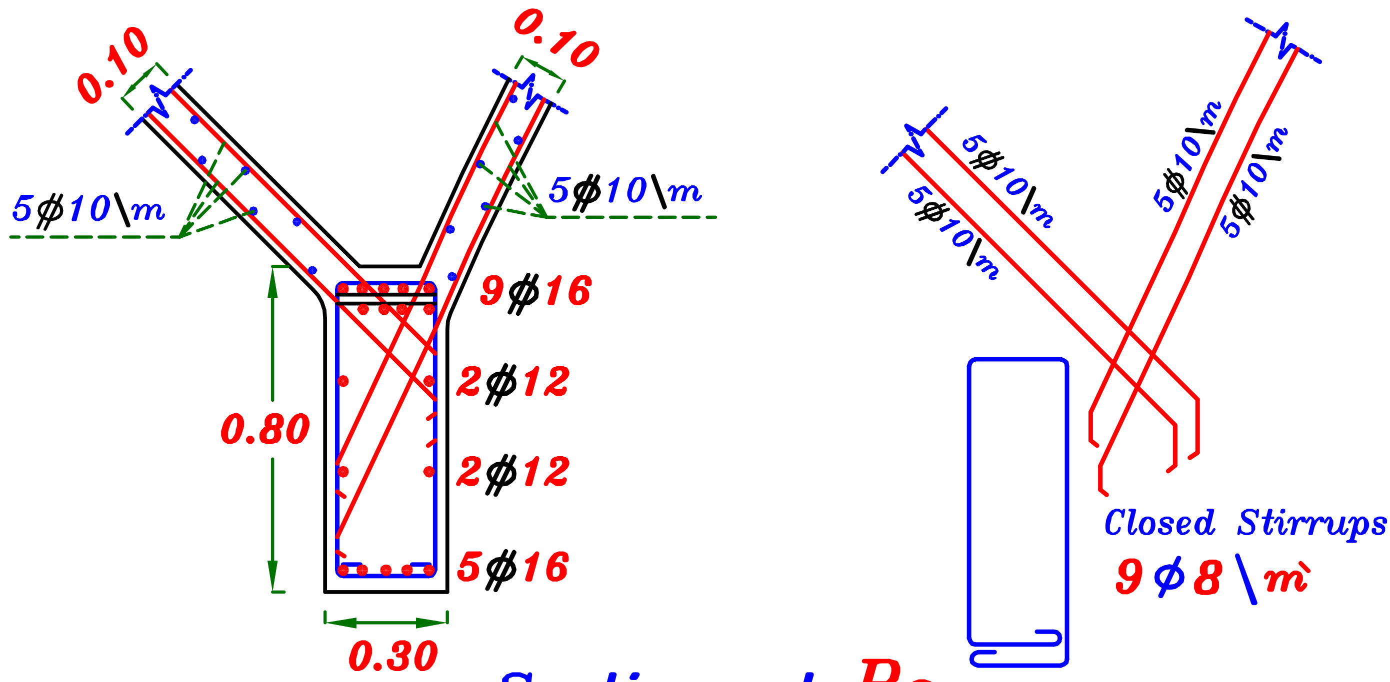
Section at B_1



Section at B_2

Plan of the Cones





Section at B_3

Example.

For the shown surface of revolution, It is required to:

1- Calculate the internal Forces at the critical sections.

2- Design the surface of revolution and draw details of RFT. in plan and cross sections.

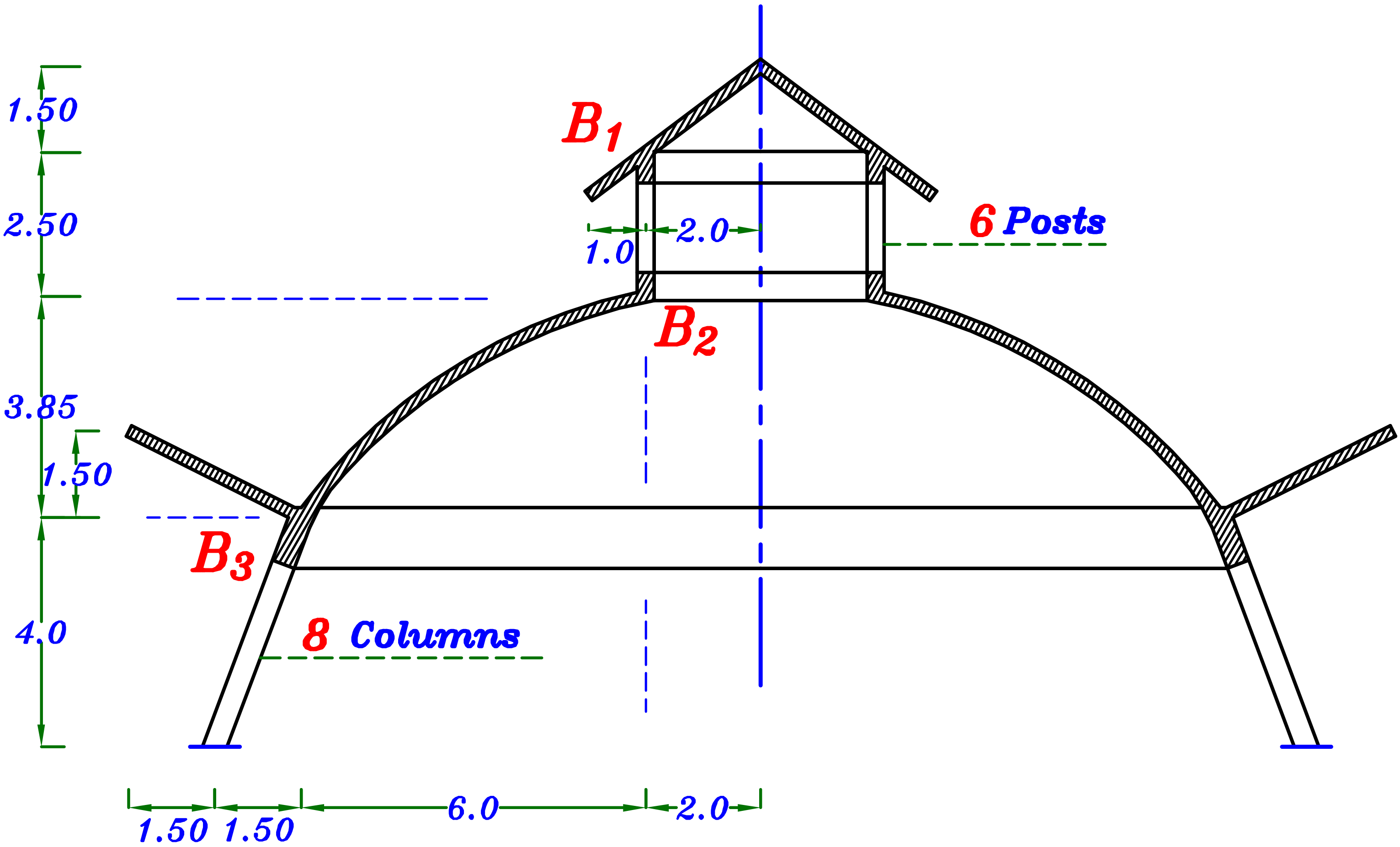
3- Design the supporting beams B_2 & B_3

Given:

$t_s = 120$ mm For all Slabs.

F.C. = 1.0 kN/m^2 , L.L. = 1.0 kN/m^2 (H.P.)

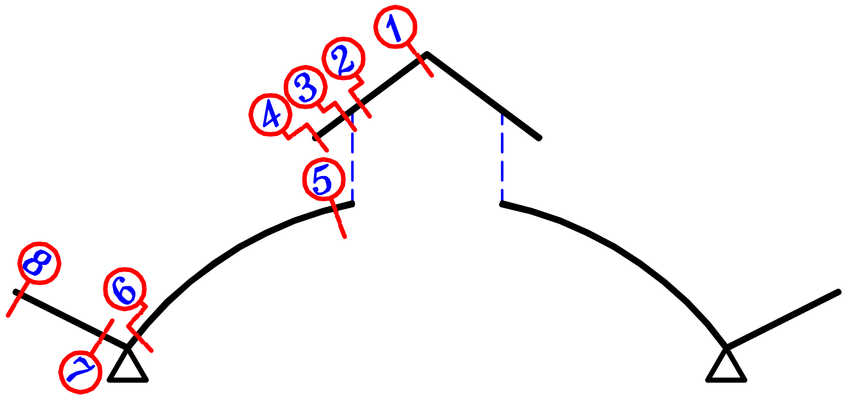
$F_{cu} = 25$ N/mm^2 , st. 360/520



Solution.

$\boxed{t_s = 120\ mm}$

as given in data

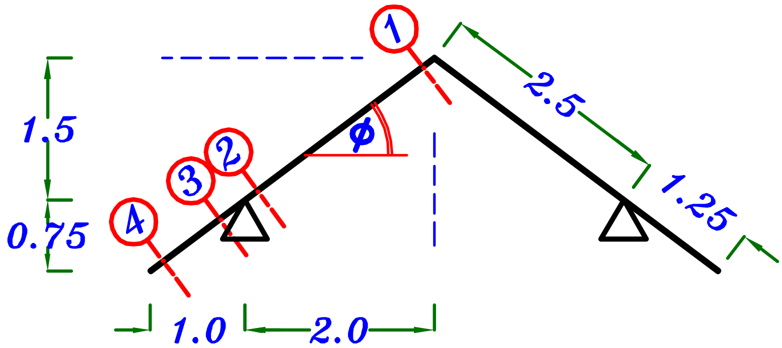


Loads.

$$g_s = t_s\ \gamma_c + F.C. = 0.12 * 25 + 1.0 = 4.0\ kN/m^2$$

$$p_s = 1.0\ kN/m^2$$

For upper Cone.



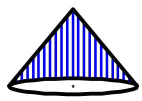
$$\tan\phi = \frac{1.5}{2.0} \longrightarrow \boxed{\phi = 36.87^\circ}$$

$$R_1 = \infty$$

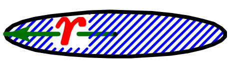
Sec. 1 Cone Vertex $(T_1)_1 = (T_2)_1 = Zero$

Sec. 2 $r = 2.0\ m$

$$S.A. = \pi * r * L = \pi * 2.0 * 2.5 = 15.71\ m^2$$



Projected area $= \pi * r^2$



$$= \pi * 2.0^2 = 12.56\ m^2$$

$$W_\phi = g * S.A. + p * \text{Projected area}$$

$$= 4.0 * 15.71 + 1.0 * 12.56 = +75.4\ kN$$

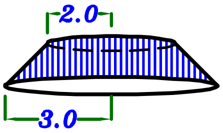
$$(T_1)_2 = \frac{W_\phi}{2\pi r\ \sin\phi} = \frac{+75.4}{2\pi * 2.0 * \sin 36.87^\circ} = +10.0\ kN/m\ \text{Comp.}$$

$$Z = g\cos\phi + p\cos^2\phi = 4.0 * \cos 36.87 + 1.0 * \cos^2 36.87 = +3.84\ kN/m^2$$

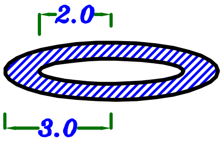
$$R_2 = \frac{r}{\sin\phi} = \frac{2.0}{\sin 36.87^\circ} = 3.33\ m$$

$$(T_2)_2 = Z * R_2 = 3.84 * 3.33 = +12.78\ kN/m\ \text{Comp.}$$

Sec. 3 $r = 2.0\ m$

$S.A. = \pi * L\,(a+b)$ 

$= \pi * 1.25 * (3.0 + 2.0) = 19.63\ m^2$

Projected area $= \pi * (r_1^2 - r_2^2)$ 

$= \pi * (3.0^2 - 2.0^2) = 15.71\ m^2$

$$W_\phi = g * S.A. + p * \text{Projected area}$$

$$= 4.0 * 19.63 + 1.0 * 15.71 = -94.23\ kN$$

$\boxed{\text{اشاره } W_\phi\ (-Ve) \text{ لان اتجاهها خارج من ال Support}}$

$$(T_1)_3 = \frac{W_\phi}{2\pi r\ Sin\phi} = \frac{-94.23}{2\pi * 2.0 * Sin\ 36.87^\circ} = -12.49\ kN/m\ \text{Ten.}$$

$$Z = g\ Cos\phi + p\ Cos^2\phi = 4.0 * Cos\ 36.87 + 1.0 * Cos^2\ 36.87 = +3.84\ kN/m^2$$

$$R_2 = \frac{r}{Sin\phi} = \frac{2.0}{Sin\ 36.87^\circ} = 3.33\ m$$

$$(T_2)_3 = Z * R_2 = 3.84 * 3.33 = +12.78\ kN/m\ \text{Comp.}$$

Sec. 4 $r = 3.0\ m$

$$W_\phi = Zero \longrightarrow (T_1)_4 = Zero$$

$$Z = g\ Cos\phi + p\ Cos^2\phi = 4.0 * Cos\ 36.87 + 1.0 * Cos^2\ 36.87 = +3.84\ kN/m^2$$

$$R_2 = \frac{r}{Sin\phi} = \frac{3.0}{Sin\ 36.87^\circ} = 5.0\ m$$

$$(T_2)_4 = Z * R_2 = 3.84 * 5.0 = +19.20\ kN/m\ \text{Comp.}$$

For beams B_1 & B_2 $\quad L = \dfrac{2\pi r}{n} = \dfrac{2*\pi*2}{6} = 2.09\ m$

$$t = \frac{L}{12} + 0.2\ m = \frac{2.09}{12} + 0.2 = 0.37 = 0.40\ m$$

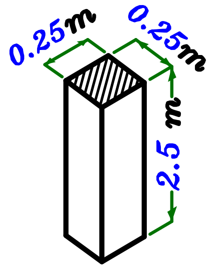
Take B_1 & B_2 (250*400)

$$o.w._{(B_1 \& B_2)} = b*t*\gamma_c = 0.25*0.40*25 = 2.50\ kN/m$$

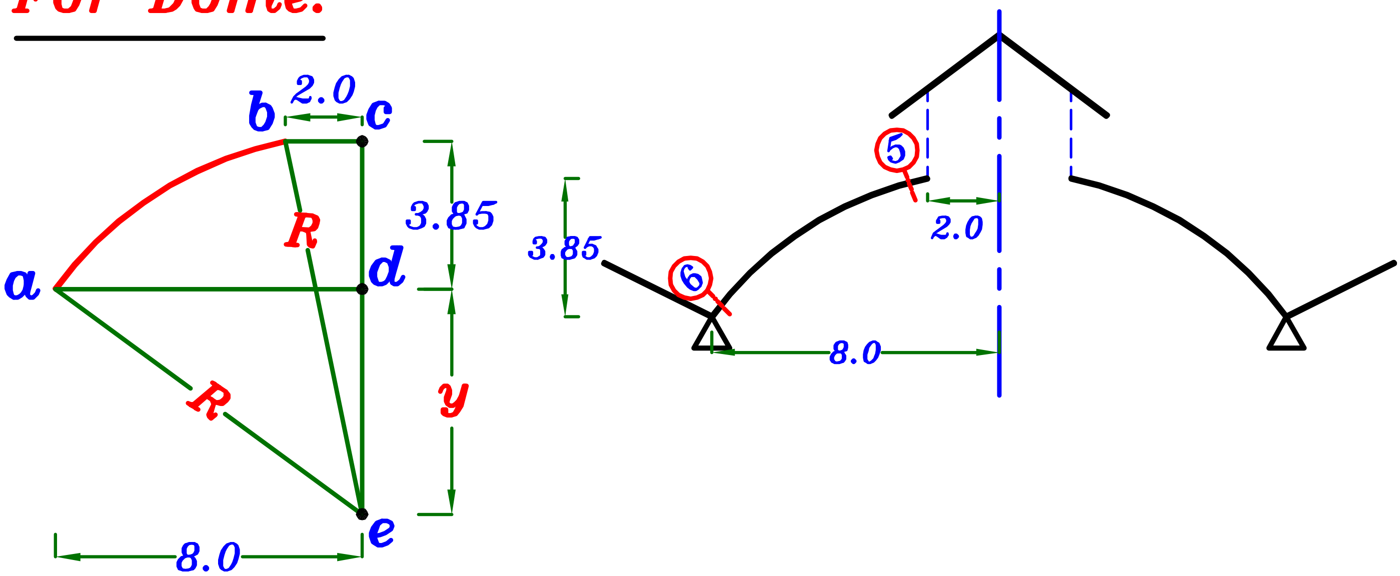
$$T.W. = \text{Total Weight}_{(B_1 \& B_2)} = o.w.*2\pi r = 2.50*2\pi*2.0 = 31.41\ kN$$

Take Post (0.25*0.25*2.50)

$$o.w._{(Post)} = 0.25*0.25*2.50*25 = 3.90\ kN$$



For Dome.



For Triangle a d e

$$R^2 = 8.0^2 + y^2 \quad \therefore R^2 = 64 + y^2 \quad \xrightarrow{R,\,y} (1)$$

For Triangle e c b

$$R^2 = 2.0^2 + (y+3.85)^2 \longrightarrow R^2 = 4.0 + y^2 + 7.70\,y + 14.82$$

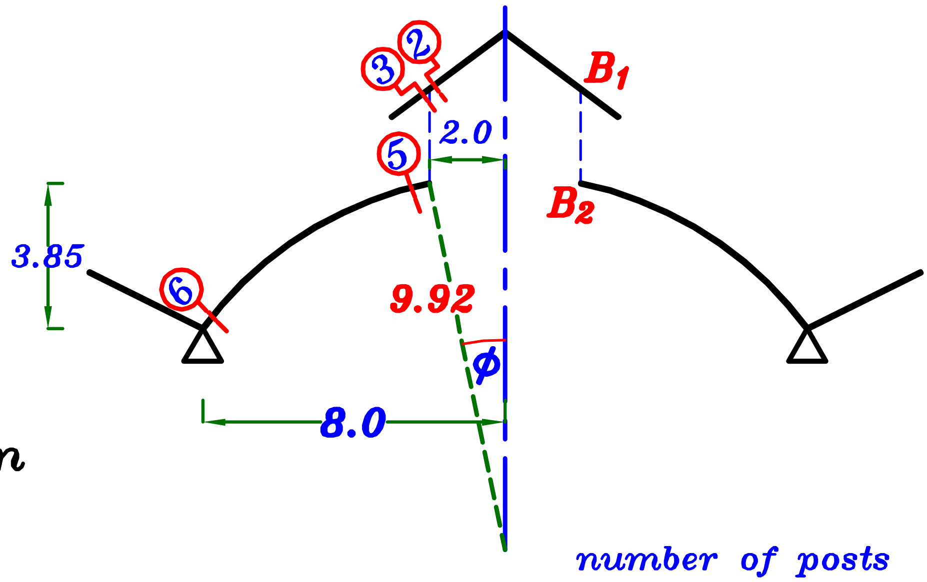
$$R^2 = 18.82 + y^2 + 7.7\,y \quad \xrightarrow{R,\,y} (2)$$

بتعويض R^2 من المعادله الاولى فى المعادله الثانيه

$$\therefore 64 + \cancel{y^2} = 18.82 + \cancel{y^2} + 7.7\,y \longrightarrow y = 5.87\ m$$

$$\therefore R^2 = 64 + 5.87^2 = 98.45\ m^2 \longrightarrow \boxed{R = 9.92\ m}$$

Sec. 5 $r = 2.0\ m$



$$\sin\phi = \frac{2.0}{9.92}$$

$$\rightarrow \boxed{\phi = 11.63^\circ}$$

$$R_1 = R_2 = R = 9.92\ m$$

number of posts

$$W_\phi = W_{\phi\,(Sec.2)} + W_{\phi\,(Sec.3)} + T.W._{(B_1)} + T.W._{(B_2)} + n * o.w._{(Post)}$$

$$W_\phi = 75.4 + 94.23 + 31.41 + 31.41 + 6 * 3.90 = +255.85\ kN$$

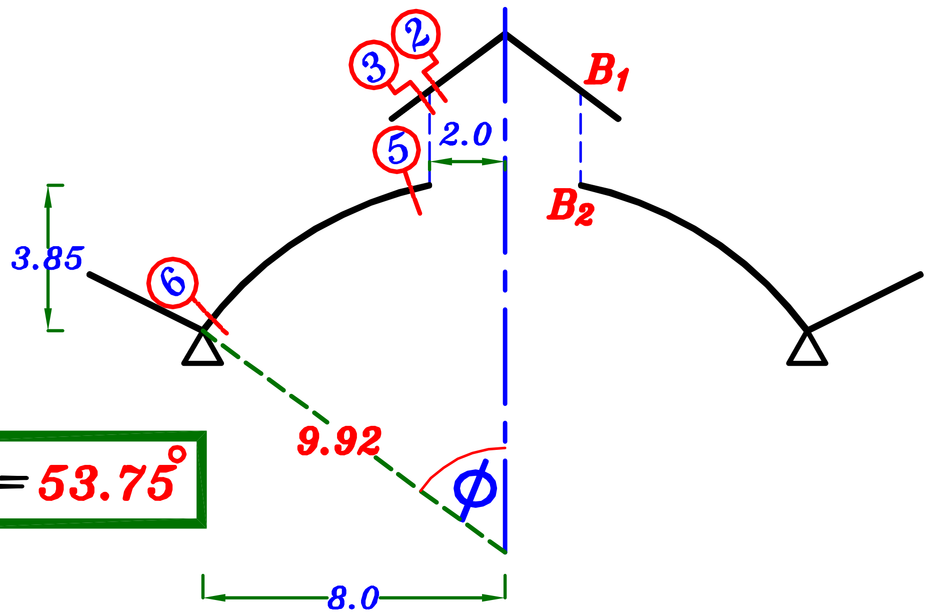
$$(T_1)_5 = \frac{W_\phi}{2\pi r\ \sin\phi} = \frac{+255.85}{2\pi * 2.0 * \sin 11.63^\circ} = +101.0\ kN/m\ \text{Comp.}$$

$$Z = g\cos\phi + p\cos^2\phi = 4.0 * \cos 11.63 + 1.0 * \cos^2 11.63 = +4.88\ kN/m^2$$

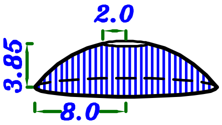
$$\because\ T_1 + T_2 = Z * R \qquad \therefore\ +101.0 + T_2 = 4.88 * 9.92$$

$$\therefore\ (T_2)_5 = -52.59\ kN/m\ \text{Ten.}$$

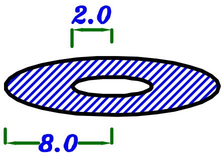
Sec. 6 $r = 8.0\ m$



$$\sin\phi = \frac{8.0}{9.92} \rightarrow \boxed{\phi = 53.75^\circ}$$

$S.A. = 2\pi * R * h$ 

$= 2\pi * 9.92 * 3.85 = 239.97 \ m^2$

Projected area $= \pi * (r_1^2 - r_2^2)$ 

$= \pi * (8.0^2 - 2.0^2) = 188.50 \ m^2$

$W_\phi = W_{\phi\,(Sec.5)} + g * S.A. + p *$ **Projected area**

$W_\phi = 255.85 + 4.0 * 239.97 + 1.0 * 188.50 = +1404.23 \ kN$

$$(T_1)_6 = \frac{W_\phi}{2\pi r \ Sin\phi} = \frac{+1404.23}{2\pi * 8.0 * Sin\, 53.75^\circ} = +34.64 \ kN/m \ \text{Comp.}$$

$$Z = g \ Cos\,\phi + p \ Cos^2\phi = 4.0 * Cos\, 53.75 + 1.0 * Cos^2 53.75 = +2.71 \ kN/m^2$$

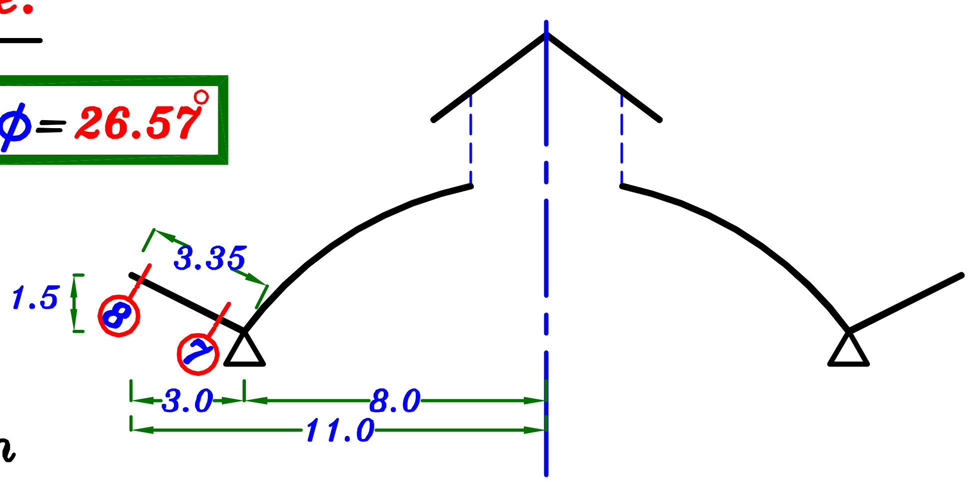
$\because T_1 + T_2 = Z * R \qquad \therefore +34.64 + T_2 = 2.71 * 9.92$

$\therefore \quad (T_2)_6 = -7.75 \quad kN/m$ **Ten.**

For lower Cone.

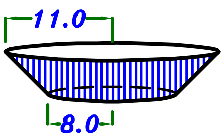
$$tan\,\phi = \frac{1.5}{3.0} \longrightarrow \boxed{\phi = 26.57^\circ}$$

$R_1 = \infty$

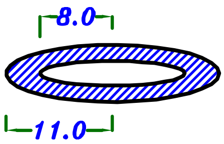


Sec. 7

$r = 8.0 \ m$

$S.A. = \pi * L \ (a+b)$ 

$= \pi * 3.35 * (11.0 + 8.0) = 199.96 \ m^2$

Projected area $= \pi * (r_1^2 - r_2^2)$ 

$= \pi * (11.0^2 - 8.0^2) = 179.1 \ m^2$

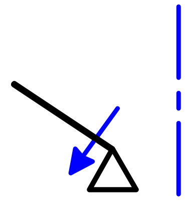
$W_\phi = g * S.A. + p *$ **Projected area**

$= 4.0 * 199.96 + 1.0 * 179.1 = 978.94 \ kN$

$$(T_1)_7 = \frac{W_\phi}{2\pi r \, Sin\phi} = \frac{978.94}{2\pi * 8.0 * Sin\, 26.57^\circ} = +\,43.54 \ kN/m \ \ Comp.$$

$$Z = g\, Cos\phi + p\, Cos^2\phi = 4.0 * Cos\, 26.57 + 1.0 * Cos^2 26.57 = -4.38 \ kN/m^2$$

اشاره Z $(-Ve)$ لان اتجاهها خارج من المحور



$$R_2 = \frac{r}{Sin\phi} = \frac{8.0}{Sin\, 26.57^\circ} = 17.88 \ m$$

$$\because \ (T_2)_7 = Z * R_2 = -4.38 * 17.88 = -\,78.31 \ kN/m \ \ Ten.$$

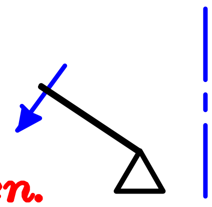
Sec. 8

$$r = 11.0 \ m$$

$$W_\phi = Zero \longrightarrow (T_1)_8 = Zero$$

$$Z = g\, Cos\phi + p\, Cos^2\phi = 4.0 * Cos\, 26.57 + 1.0 * Cos^2 26.57 = -4.38 \ kN/m^2$$

$$R_2 = \frac{r}{Sin\phi} = \frac{11.0}{Sin\, 26.57^\circ} = 24.60 \ m$$



$$(T_2)_8 = Z * R_2 = -4.38 * 24.60 = -107.75 \ kN/m \ \ Ten.$$

Design of Sections.

For the upper Cone.

Sec. 1, Sec. 2, Sec. 3 & Sec. 4

$$(T_{max}) = 19.20 \ kN/m \ \ Comp.$$

$$Actual\ Stress = \frac{T_{max}}{A_c} = \frac{T_{max}}{1000 * t_s} = \frac{19.20 * 10^3}{1000 * 120} = 0.16 \ N/mm^2$$

$$F_{cu} = 25 \ N/mm^2 \longrightarrow F_{co} = 6.0 \ N/mm^2$$

$$Allowable\ Stress = \frac{F_{co}}{2} = \frac{6.0}{2} = 3.0 \ N/mm^2$$

$$Actual\ Stress < Allowable\ Stress \longrightarrow t_s = 120 \ mm \text{ is o.k.}$$

To Get T_1 RFT. $\longrightarrow$ max. Tension $T_1 = 12.49$ kN/m

$$As_{(T_1)} = \frac{T_1\ (U.L.)}{F_y \backslash \delta_s} = \frac{1.5 * 12.49 * 10^3}{360 \backslash 1.15} = 59.85\ mm^2/m$$

$$As_{(T_1)} \backslash Side = \frac{59.85}{2} = 29.93\ mm^2/m \xrightarrow{\text{use min. RFT.}} 5\phi 10 \backslash m' \text{ each Side}$$

To Get T_2 RFT. $\longrightarrow$ No Tension $\xrightarrow{\text{use min. RFT.}}$ $5\phi 10 \backslash m'$ each Side

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For Dome. Sec. ⑤ & Sec. ⑥

$(T_{max}) = 101.0$ kN/m Comp.

$$\text{Actual Stress} = \frac{T_{max}}{A_c} = \frac{T_{max}}{1000 * t_s} = \frac{101.0 * 10^3}{1000 * 120} = 0.841\ N/mm^2$$

$$F_{cu} = 25\ N/mm^2 \longrightarrow F_{co} = 6.0\ N/mm^2$$

$$\text{Allawable Stress} = \frac{F_{co}}{2} = \frac{6.0}{2} = 3.0\ N/mm^2$$

Actual Stress < Allawable Stress $\longrightarrow$ $t_s = 120$ mm is o.k.

To Get T_1 RFT. $\longrightarrow$ No Tension $\xrightarrow{\text{use min. RFT.}}$ $5\phi 10 \backslash m'$ each Side

To Get T_2 RFT. $\longrightarrow$ max. Tension $T_2 = 52.59$ kN/m

$$As_{(T_2)} = \frac{T_2\ (U.L.)}{F_y \backslash \delta_s} = \frac{1.5 * 52.59 * 10^3}{360 \backslash 1.15} = 252.0\ mm^2/m$$

$$As_{(T_2)} \backslash Side = \frac{252.0}{2} = 126.0\ mm^2/m \xrightarrow{\text{use min. RFT.}} 5\phi 10 \backslash m' \text{ each Side}$$

For Lower Cone. Sec. ⑦ & Sec. ⑧

$(T_{max}) = 43.54$ kN/m Comp.

$$\text{Actual Stress} = \frac{T_{max}}{A_c} = \frac{T_{max}}{1000 * t_s} = \frac{43.54 * 10^3}{1000 * 120} = 0.363\ N/mm^2$$

$$F_{cu} = 25\ N/mm^2 \longrightarrow F_{co} = 6.0\ N/mm^2$$

$$\text{Allawable Stress} = \frac{F_{co}}{2} = \frac{6.0}{2} = 3.0\ N/mm^2$$

Actual Stress < Allawable Stress $\longrightarrow$ $t_s = 120$ mm is o.k.

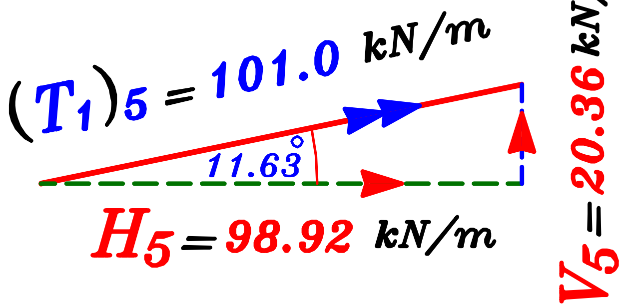
To Get T_1 RFT. $\longrightarrow$ No Tension $\xrightarrow{\text{use min. RFT.}}$ $5\phi 10\backslash m'$ each Side

To Get T_2 RFT. $\longrightarrow$ max. Tension $T_2 = 107.75$ kN/m

$$As_{(T_2)} = \frac{T_{2\,(U.L.)}}{F_y \backslash \gamma_s} = \frac{1.5 * 107.75 * 10^3}{360 \backslash 1.15} = 516.3 \ mm^2/m$$

$$As_{(T_2)} \backslash Side = \frac{516.3}{2} = 258.15 \ mm^2/m \xrightarrow{\text{use min. RFT.}} 5\phi 10\backslash m' \text{ each Side}$$

Design of Beam B_2 (250 * 400)



$$o.w._{(B_2)} = b * t * \gamma_c = 2.50 \ kN/m$$

$$w = V_5 - o.w. = 20.36\uparrow - 2.50\downarrow = 17.86 \ kN/m$$

$\boxed{V_5 \text{ اتجاهها لاعلى لكن ال } o.w. \text{ اتجاهه لاسفل}}$

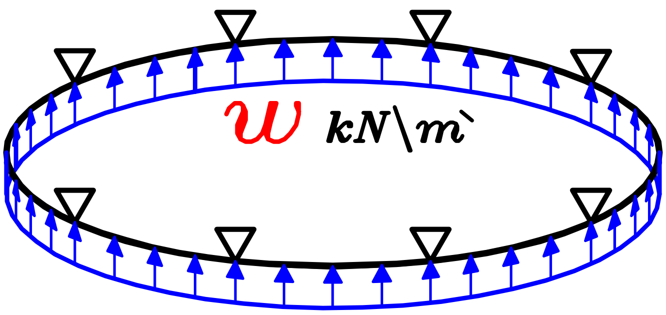
$H = H_5 = 98.92$ kN/m للداخل

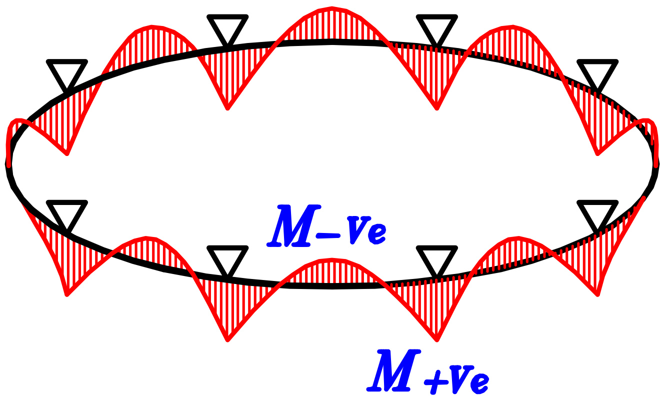
Compression Force on Beam $= H * r$

$$= 98.92 * 2.0 = 197.84 \ kN$$

لان الحمل المنتظم على الكمره اتجاهه من اسفل الى اعلى اذا سينعكس اتجاه العزم

و ستنعكس قيمه كلا من ($max. M_{-Ve}$) و ($max. M_{+Ve}$)





From Tables $n = 6.0$

No. of supports	Load on each support	Max. Shearing Force	Max. Bending Moment at C.L. of Span	Max. Bending Moment Over C.L. of Column	Max. Torsional Moment	Central angle
n	R	$Q_{max.}$	M +Ve	M −Ve	$M_{t\,max.}$	θ
4	P/4	P/8	0.0176 Pr	− 0.0322 Pr	0.0053 Pr	19° 21`
6	P/6	P/12	0.0075 Pr	− 0.0148 Pr	0.0015 Pr	12° 44`
8	P/8	P/16	0.0042 Pr	− 0.0083 Pr	0.0006 Pr	9° 33`
10	P/10	P/20	0.0032 Pr	− 0.0052 Pr	0.0004 Pr	7° 36`
12	P/12	P/24	0.0019 Pr	− 0.0037 Pr	0.0002 Pr	6° 21`

$$P = w * 2\pi r = 17.86 * 2\pi * 2.0 = 224.44 \text{ kN}$$

$$\max.\ M_{+Ve} = 0.0148\, Pr = 0.0148 * 224.44 * 2.0 = 6.643 \text{ kN.m}$$

$$\max.\ M_{-Ve} = 0.0075\, Pr = 0.0075 * 224.44 * 2.0 = 3.367 \text{ kN.m}$$

$$\max.\ M_t = 0.0015\, Pr = 0.0015 * 224.44 * 2.0 = 0.673 \text{ kN.m}$$

$$Q_{max.} = \frac{P}{12} = \frac{224.44}{12} = 18.70 \text{ kN}$$

Central angle $\theta = 12^\circ\ 44` = 12.73^\circ$

$$X = r * \theta * \frac{\pi}{180} = 2.0 * 12.73 * \frac{\pi}{180} = 0.44 \text{ m}$$

$$Q_{cor.} = Q_{max} - w * X = 18.70 - 17.86 * 0.44 = 10.84 \text{ kN}$$

Design beam B_1 on M & P

$b = 250$ mm , $t = 400$ mm

Sec. of max. + Ve B.M.

$M = 6.643 * 1.5 = 9.96$ kN.m. , $P = 197.84 * 1.5 = 296.76$ kN

Check $\dfrac{P}{F_{cu}\, b\, t} = \dfrac{296.76 * 10^3}{25 * 250 * 400} = 0.11 > 0.04$ (Don't Neglect P)

$\therefore$ Design the Sec. on both N.F. & B.M.

$$e = \frac{M}{P} = \frac{9.96}{296.76} = 0.033 \text{ m}$$

$$\frac{e}{t} = \frac{0.033}{0.40} = 0.084 < 0.50 \longrightarrow \text{Compression Failure} \xrightarrow{\text{use}} \text{I.D.}$$

$\therefore$ Use Interaction Diagram

$$\zeta = \frac{400 - 100}{400} = 0.75 = 0.70 \xrightarrow{\text{use}} \text{ECCS Design Aids Page } 4\text{–}25$$

$$\left.\begin{array}{l} \dfrac{P}{F_{cu}\, b\, t} = \dfrac{296.76 * 10^3}{25 * 250 * 400} = 0.11 \\ \dfrac{M}{F_{cu}\, b\, t^2} = \dfrac{9.96 \quad * 10^6}{25 * 250 * 400^2} = 0.01 \end{array}\right\} \rho < 1.0 \xrightarrow{\text{Take}} \rho = 1.0$$

$$\mu = \rho * F_{cu} * 10^{-4} = 1.0 * 25 * 10^{-4} = 2.50 * 10^{-3}$$

$$A_s = A_{s`} = \mu * b * t = 2.50 * 10^{-3} * 250 * 400 = 250.0 \text{ mm}^2$$

$$A_{s\,Total} = A_s + A_{s`} = 2 * 250 = 500 \text{ mm}^2$$

Check $A_{s\,min.} = \dfrac{0.8}{100} * b * t = \dfrac{0.8}{100} * 250 * 400 = 800 \text{ mm}^2$

$\therefore A_{s\,Total} < A_{s\,min.}$ $\quad \therefore$ Take $A_{s\,Total} = A_{s\,min.}$

$$\therefore A_s = A_{s`} = \frac{A_{s\,min.}}{2} = \frac{800}{2} = 400 \text{ mm}^2$$

Sec. of max. − Ve B.M.

Take $A_s = A_{s`} = \dfrac{A_{s\,min.}}{2} = 400 \text{ mm}^2$

Design due to Shear & Torsion.

$b = 250$ mm , $t = 400$ mm

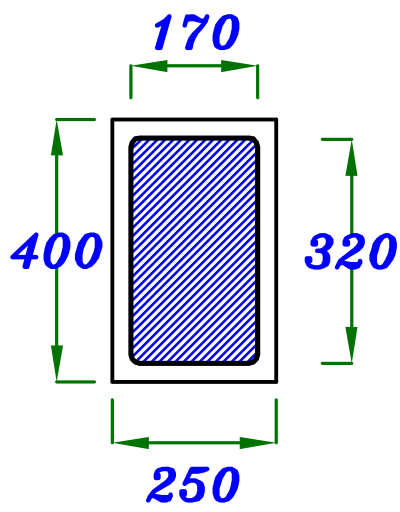
$$q_u = \frac{Q}{b\,d} = \frac{1.5 * 10.84 * 10^3}{250 * 350} = 0.186 \ N/mm^2$$

$$A_{oh} = 170 * 320 = 54400 \ mm^2$$

$$A_o = 0.85 * A_{oh} = 0.85 * 54400 = 46240 \ mm^2$$

$$P_h = 2 * 170 + 2 * 320 = 980 \ mm$$

$$t_e = \frac{A_{oh}}{P_h} = \frac{54400}{980} = 55.51 \ mm$$



$$q_{tu} = \frac{M_{tu}}{2\,A_o\,t_e} = \frac{1.5 * 0.673 * 10^6}{2 * 46240 * 55.51} = 0.196 \ N/mm^2$$

$$q_{cu} = (0.24)\sqrt{\frac{25}{1.5}} = 0.98 \ N/mm^2$$

$$q_{t\,min} = (0.06)\sqrt{\frac{25}{1.5}} = 0.245 \ N/mm^2$$

$$q_{u\,max} = (0.7)\sqrt{\frac{25}{1.5}} = 2.85 \ N/mm^2$$

$$\sqrt{q_u^2 + q_{tu}^2} = \sqrt{0.186^2 + 0.196^2} = 0.27 \ N/mm^2 < q_{u\,max} \ \therefore \text{o.k.}$$

$$\boxed{q_u < q_{cu} \ , \ q_{tu} < q_{t\,min}}$$

$\therefore$ **Use min. Stirrups** $\boxed{5 \phi 8 \backslash m'}$

2 branches.

No need to use Longitudinal Bars

$$A_{s\,total} = A_s = 400 \ mm^2$$

$4 \phi 12$

Design of Beam B_3

$$L = \frac{2\pi r}{n} = \frac{2 * \pi * 8}{8} = 6.28\ m$$

$$t = \frac{L}{12} + 0.2\ m$$

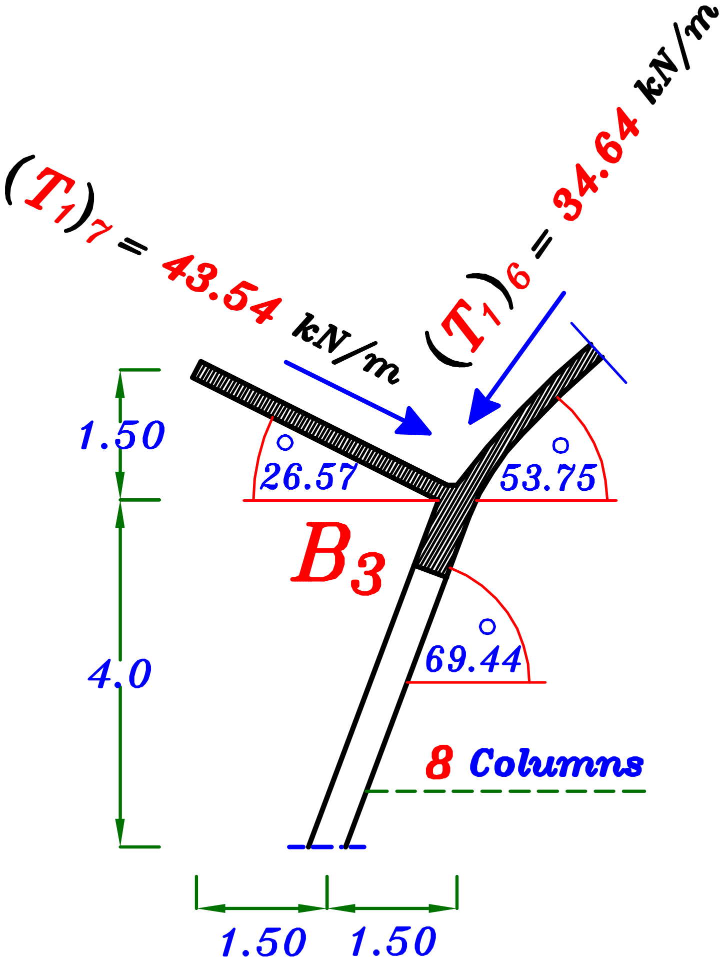
$$= \frac{6.28}{12} + 0.2 = 0.72 = 0.75\ m$$

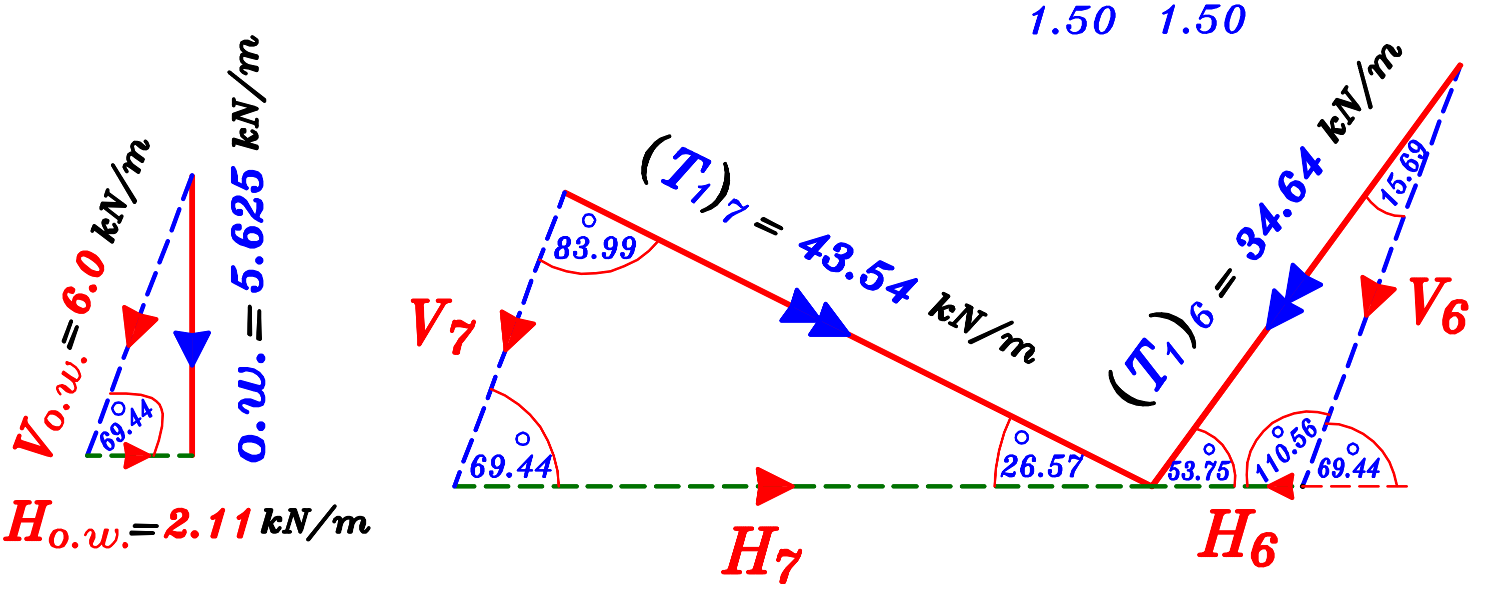
Take B_3 $(300 * 750)$

$$o.w._{(B_3)} = b * t * \gamma_c$$

$$= 0.30 * 0.75 * 25$$

$$= 5.625\ kN/m$$





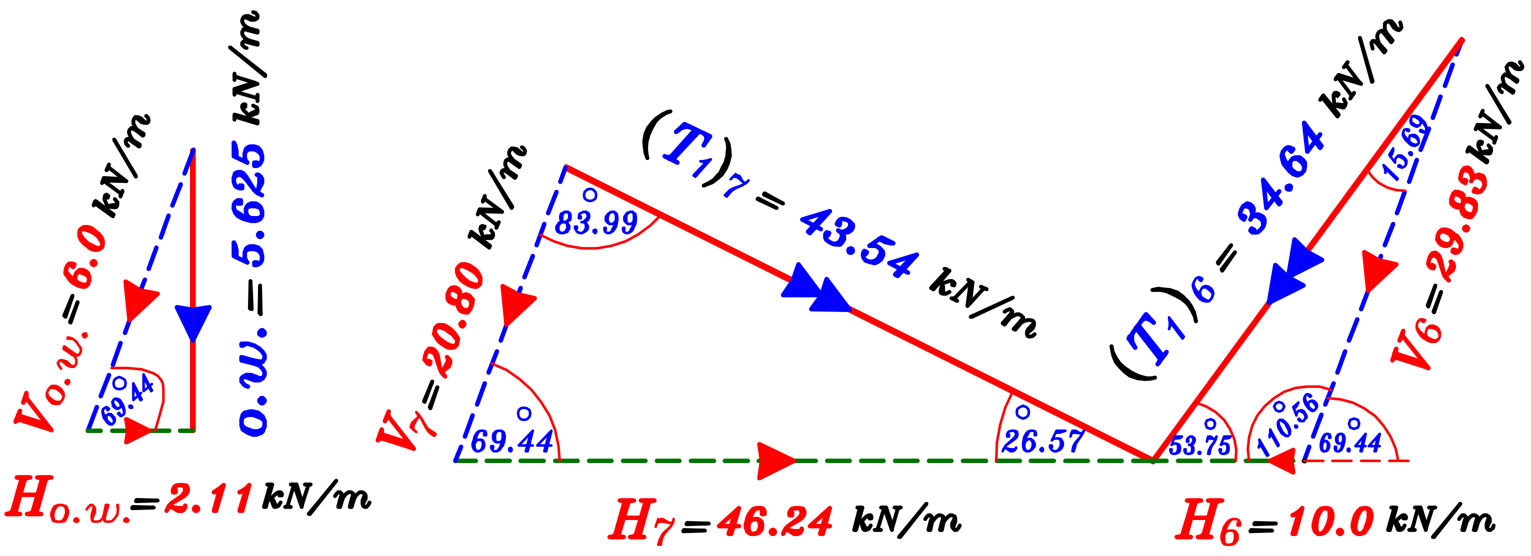
Use Sin Rule

$$\frac{34.64}{\sin 110.56} = \frac{V_6}{\sin 53.75} = \frac{H_6}{\sin 15.69} \longrightarrow V_6 = 29.83\ kN/m$$

$$H_6 = 10.0\ kN/m$$

$$\frac{43.54}{\sin 69.44} = \frac{V_7}{\sin 26.57} = \frac{H_7}{\sin 83.99} \longrightarrow V_7 = 20.80\ kN/m$$

$$H_7 = 46.24\ kN/m$$



$$w_{(Beam)} = V_{o.w.} + V_6 + V_7$$

$$= 6.0 + 29.83 + 20.80 = 56.63 \text{ kN/m}$$

$$H_{(Beam)} = H_7 - H_6 + H_{o.w.}$$

$$= 46.24 - 10.0 + 2.11 = 38.35 \text{ kN/m}$$ للداخل

$$\text{Compression Force on Beam} = H * r$$

$$= 38.35 * 8.0 = 306.8 \text{ kN}$$

From Tables $n = 8.0$

No. of supports	Load on each support	Max. Shearing Force	Max. Bending Moment at C.L. of Span	Max. Bending Moment Over C.L. of Column	Max. Torsional Moment	Central angle
n	R	$Q_{max.}$	$M\ +Ve$	$M\ -Ve$	$M_{t\,max.}$	θ
4	P/4	P/8	0.0176 P r	– 0.0322 P r	0.0053 P r	19° 21`
6	P/6	P/12	0.0075 P r	– 0.0148 P r	0.0015 P r	12° 44`
8	**P/8**	**P/16**	**0.0042 P r**	**– 0.0083 P r**	**0.0006 P r**	**9° 33`**
10	P/10	P/20	0.0032 P r	– 0.0052 P r	0.0004 P r	7° 36`
12	P/12	P/24	0.0019 P r	– 0.0037 P r	0.0002 P r	6° 21`

$n = 8.0$

$P = w * 2\pi r = 56.63 * 2\pi * 8.0 = 2846.53 \ kN$

$max.\ M_{+Ve} = 0.0042\ P r = 0.0042 * 2846.53 * 8.0 = 95.64 \ kN.m$

$max.\ M_{-Ve} = 0.0083\ P r = 0.0083 * 2846.53 * 8.0 = 189.0 \ kN.m$

$max.\ M_t = 0.0006\ P r = 0.0006 * 2846.53 * 8.0 = 13.66 \ kN.m$

$Q_{max.} = \frac{P}{16} = \frac{2846.53}{16} = 177.91 \ kN$

Central angle $\theta = 9^\circ 33' = 9.55^\circ$

$X = r * \theta * \frac{\pi}{180} = 8.0 * 9.55 * \frac{\pi}{180} = 1.33 \ m$

$Q_{cor.} = Q_{max} - w * X = 177.91 - 56.63 * 1.33 = 102.59 \ kN$

Design beam B3 on M & P $b = 300 \ mm$, $t = 750 \ mm$

Sec. of max. − Ve B.M.

$M = 189.0 * 1.5 = 283.5 \ kN.m.$, $P = 306.8 * 1.5 = 460.2 \ kN$

Check $\frac{P}{F_{cu}\, b\, t} = \frac{460.2 * 10^3}{25 * 300 * 750} = 0.082 > 0.04$ (Don't Neglect P)

$e = \frac{M}{P} = \frac{283.5}{460.2} = 0.616 \ m$

$\therefore \frac{e}{t} = \frac{0.616}{0.75} = 0.82 > 0.5 \xrightarrow{Use} e_s$

$e_s = e + \frac{t}{2} - c = 0.616 + \frac{0.75}{2} - 0.05 = 0.941 \ m$

$M_s = P * e_s = 460.2 * 0.941 = 433.05 \ kN.m$

$\therefore d = C_1 \sqrt{\frac{M_s}{F_{cu}\, b}}$ $\therefore 700 = C_1 \sqrt{\frac{433.05 * 10^6}{25 * 300}} \rightarrow C_1 = 2.91 \rightarrow J = 0.734$

$$\therefore A_s = \frac{M_s}{J\,F_y\,d} - \frac{P_{U.L.}}{(F_y \backslash \gamma_s)}$$

$$= \frac{433.05 * 10^6}{0.734 * 360 * 700} - \frac{460.2 * 10^3}{(360 \backslash 1.15)} = 871.13 \ mm^2$$

Check $A_{s_{min.}}$ $\qquad A_{s_{req.}} = 871.13 \ mm^2$

$$\mu_{min.}\,b\,d = \left(0.225 * \frac{\sqrt{F_{cu}}}{F_y}\right) b\,d = \left(0.225 * \frac{\sqrt{25}}{360}\right) 300 * 700 = 656.25 \ mm^2$$

$$\therefore A_{s_{req.}} > \mu_{min.}\,b\,d \quad \therefore \text{Take } A_s = A_{s_{req.}} = 871.13 \ mm^2$$

Sec. of max. +Ve B.M.

$$M = 95.64 * 1.5 = 143.46 \ kN.m.$$

$$\therefore d = C_1 \sqrt{\frac{M_{U.L.}}{F_{cu}\,b}} \quad \therefore 700 = C_1 \sqrt{\frac{143.46 * 10^6}{25 * 300}} \rightarrow C_1 = 5.06 \rightarrow J = 0.826$$

$$\therefore A_s = \frac{M_{U.L.}}{J\,F_y\,d} = \frac{143.46 * 10^6}{0.826 * 360 * 700} = 689.2 \ mm^2$$

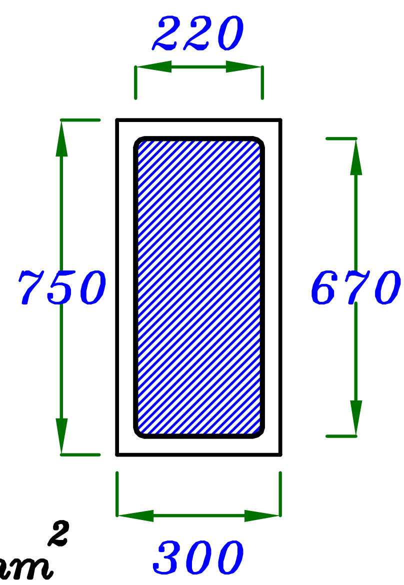
Check $A_{s_{min.}}$ $\qquad A_{s_{req.}} = 689.2 \ mm^2$

$$\mu_{min.}\,b\,d = \left(0.225 * \frac{\sqrt{F_{cu}}}{F_y}\right) b\,d = \left(0.225 * \frac{\sqrt{25}}{360}\right) 300 * 700 = 656.25 \ mm^2$$

$$\therefore A_{s_{req.}} > \mu_{min.}\,b\,d \quad \therefore \text{Take } A_s = A_{s_{req.}} = 689.2 \ mm^2$$

Design due to Shear & Torsion.

$$q_u = \frac{Q}{b\,d} = \frac{1.5 * 102.59 * 10^3}{300 * 700} = 0.732 \ N/mm^2$$



$$A_{oh} = 220 * 670 = 147400 \ mm^2$$

$$A_o = 0.85 * A_{oh} = 0.85 * 147400 = 125290 \ mm^2$$

$$P_h = 2 * 220 + 2 * 670 = 1780 \ mm$$

$$t_e = \frac{A_{oh}}{P_h} = \frac{147400}{1780} = 82.81 \ mm$$

$$q_{tu} = \frac{M_{tu}}{2\,A_o\,t_e} = \frac{1.5 * 13.66 * 10^6}{2 * 125290 * 82.81} = 0.987 \ N/mm^2$$

$$q_{cu} = (0.24)\sqrt{\frac{25}{1.5}} = 0.98 \ N/mm^2$$

$$q_{t\,min} = (0.06)\sqrt{\frac{25}{1.5}} = 0.245 \ N/mm^2$$

$$q_{u\,max} = (0.7)\sqrt{\frac{25}{1.5}} = 2.85 \ N/mm^2$$

$$\sqrt{q_u^2 + q_{tu}^2} = \sqrt{0.732^2 + 0.987^2} = 1.229 \ N/mm^2 < q_{u\,max} \quad \therefore \text{o.k.}$$

$$\boxed{q_u < q_{cu} \ , \ q_{tu} > q_{t\,min}}$$ $\therefore$ Use RFT. For Torsion only.

* **Stirrups.**

$$\therefore A_{str} = \frac{M_{tu}\ S_t}{(1.7)\ A_{oh}\ \left(\frac{F_y}{\gamma_s}\right)} \qquad \therefore A_{str} = \frac{(1.5 * 13.66 * 10^6) * S_t}{(1.7)(147400)(240/1.15)}$$

$$\therefore \boxed{S_t = 2.552 * A_{str}}$$

* Take $\phi\ 8 \longrightarrow A_{str} = 50.3\ mm^2$

$\therefore S_t = 2.552 * A_{str} = 2.552 * 50.3 = 128.36\ mm > 100\ mm \quad \therefore$ o.k.

$\therefore$ No. of stirrups\m` $= \frac{1000}{S} = \frac{1000}{128.36} = 7.79 = 8.0$

$\therefore$ Use Closed Stirrups $\boxed{8 \phi 8 \backslash m`}$ 2 branches.

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* **Longitudinal Bars.** $\qquad S_t = \frac{1000}{8} = 125\ mm$

$$A_{sl} = \frac{A_{str} * P_h}{S_t}\left(\frac{F_{y\,str.}}{F_{y\,L.b.}}\right) = \frac{(50.3 * 1780)}{125}\left(\frac{240}{360}\right) = 477.51\ mm^2$$

$$\therefore \frac{A_{sl}}{4} = \frac{477.51}{4} = 119.38\ mm^2$$

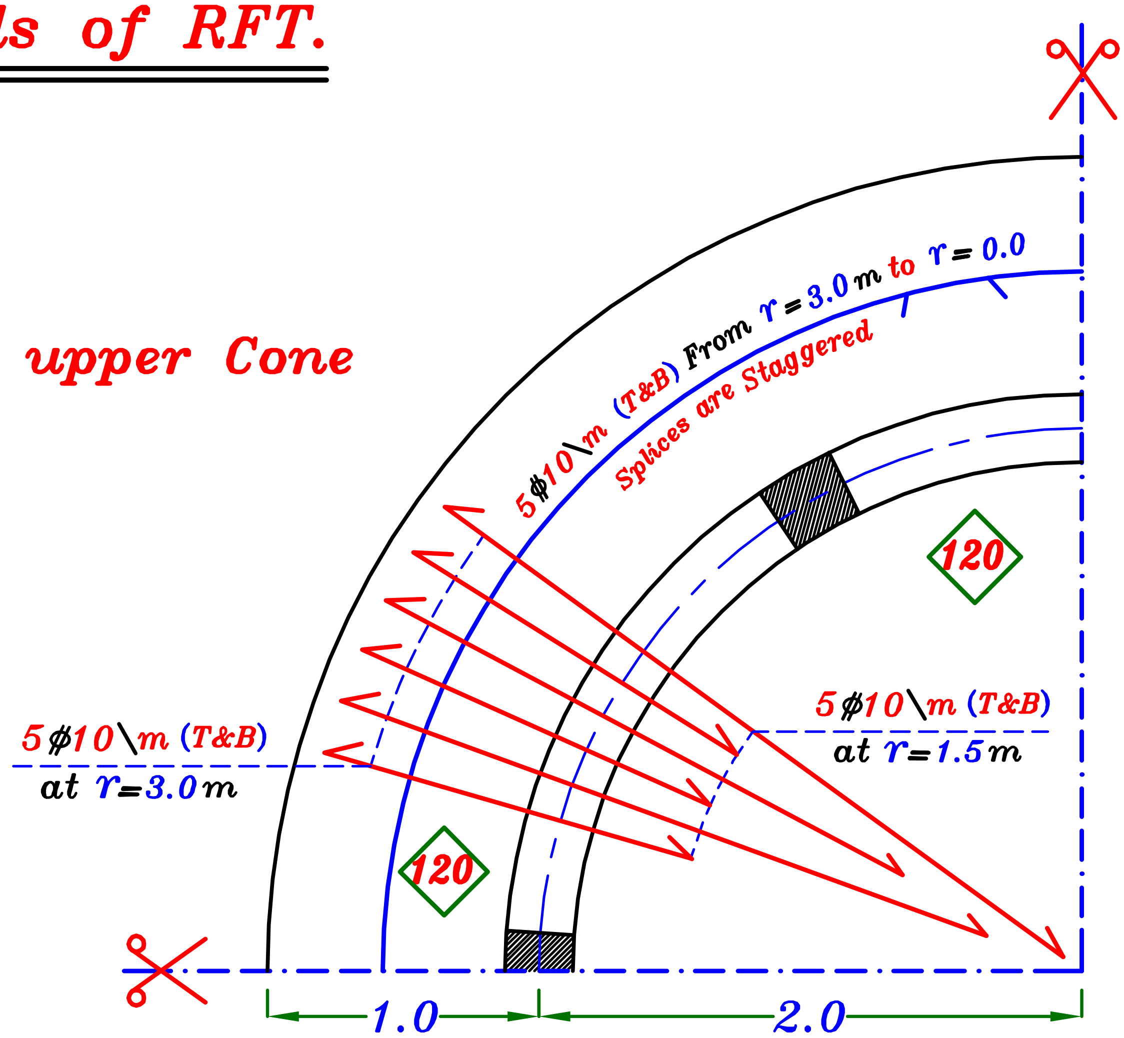
$$A_{s-ve} = A_s + \frac{A_{sl}}{4} = 871.13 + 119.38 = 990.51\ mm^2 \qquad 5 \phi 16$$

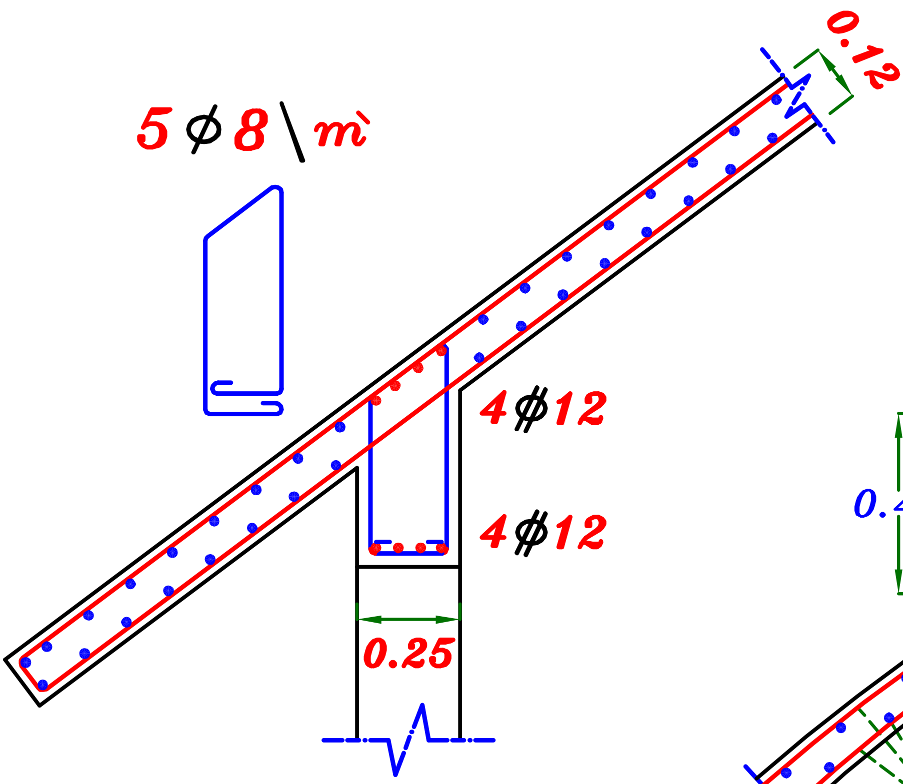
$$\therefore n = \frac{b - 25}{\phi + 25} = \frac{300 - 25}{16 + 25} = 6.70 = 6.0$$

$$A_{s+ve} = A_s + \frac{A_{sl}}{4} = 689.2 + 119.38 = 808.58\ mm^2 \qquad 5 \phi 16$$

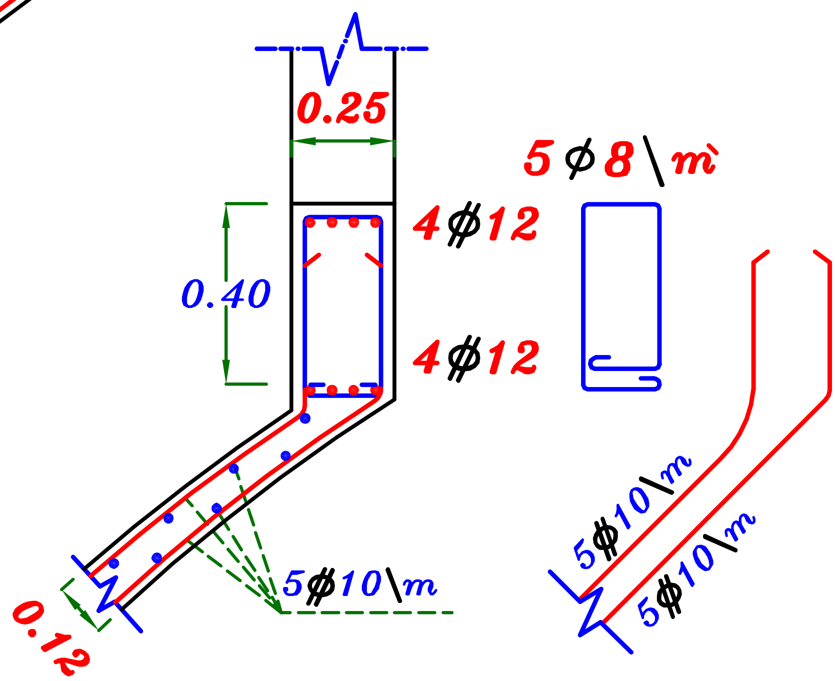
Details of RFT.

Plan of upper Cone



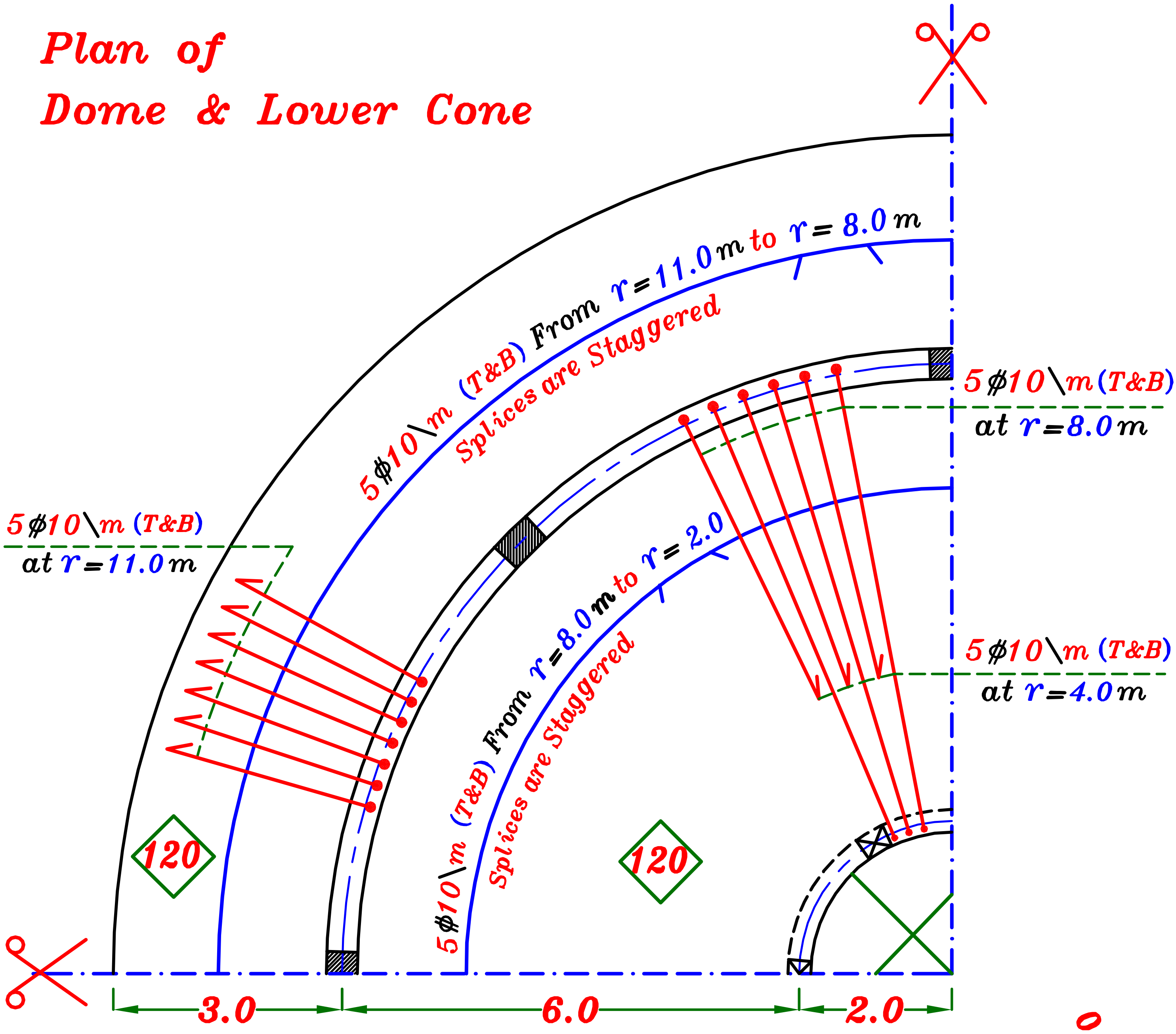


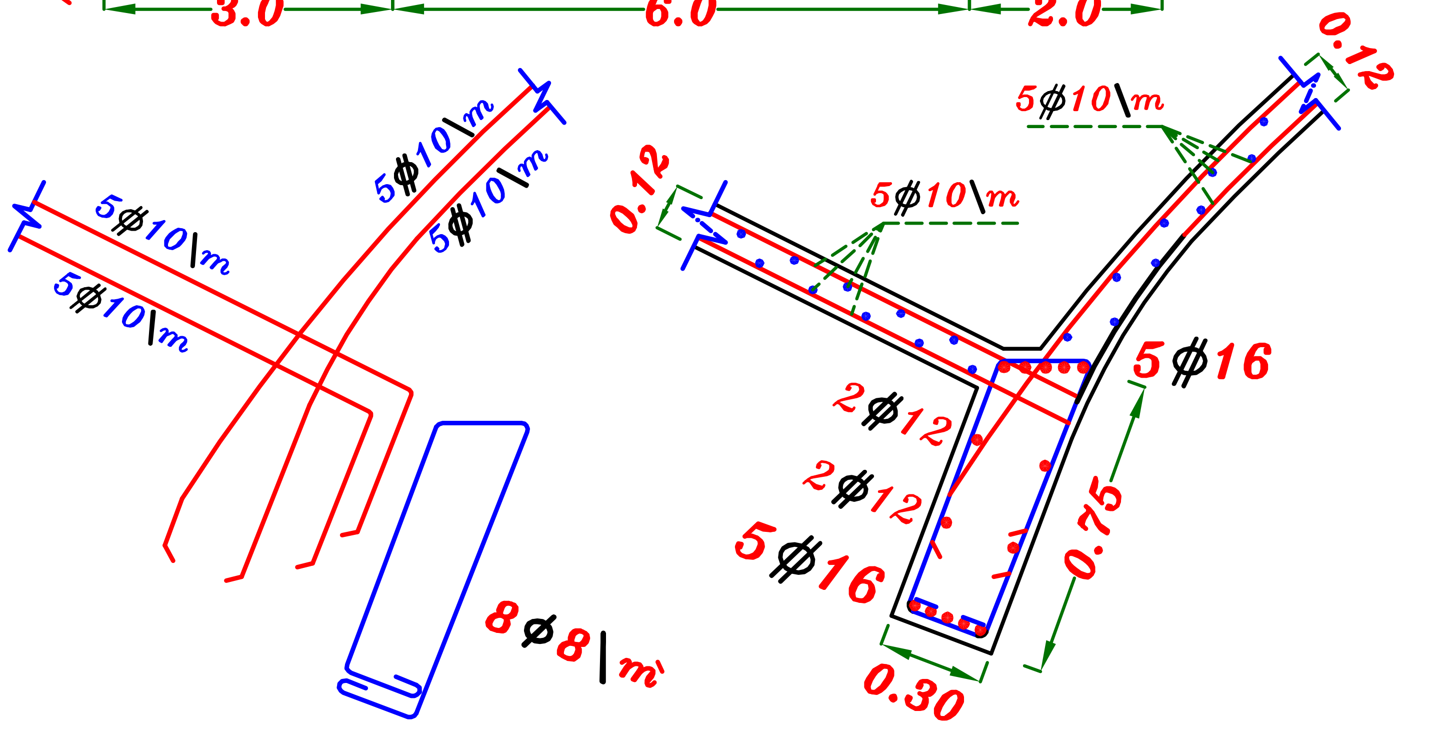
Section at B_1



Section at B_2

Plan of Dome & Lower Cone





Section at B_3

Example.

For the shown surface of revolution, It is required to:

1- Calculate the internal Forces at the critical sections.

2- Design the surface of revolution and draw details of RFT. in plan and cross sections.

3- Design the supporting beam B_3 and draw its details of RFT. in Elevation & Cross Section.

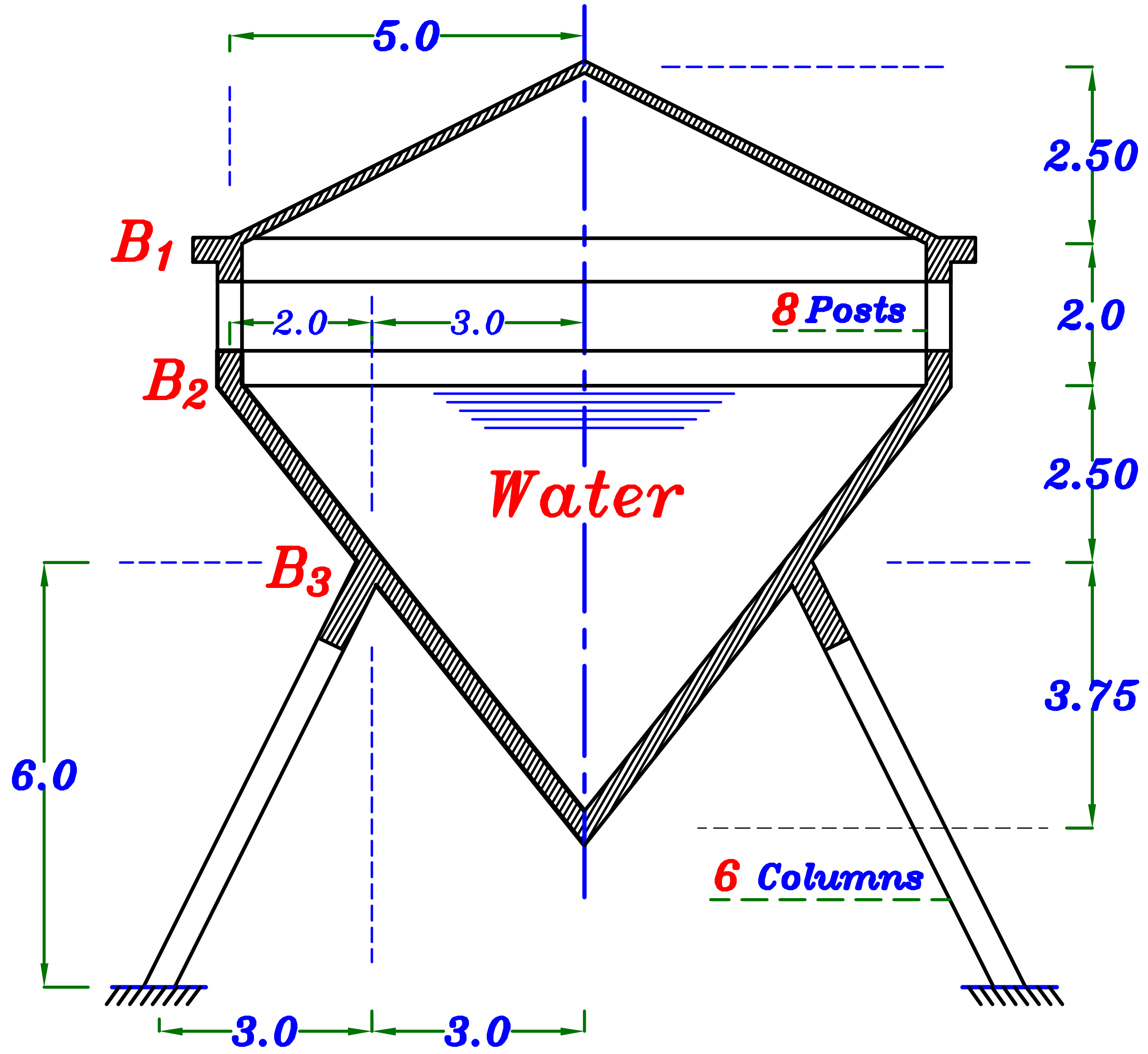
Given:

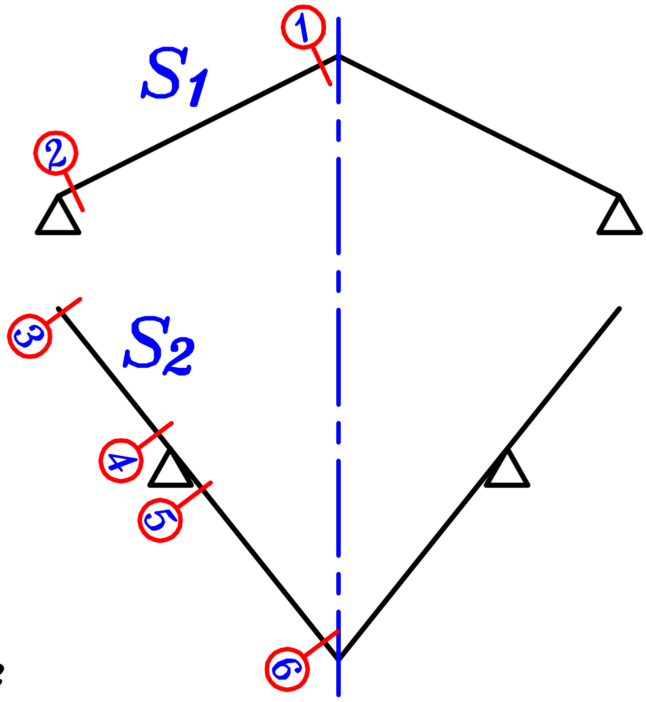
$F_{cu} = 25 \ N/mm^2$, st. 360/520

For Upper Cone.

$t_s = 100 \ mm$ $\quad$ $F.C. = 0.5 \ kN/m^2$, $L.L. = 0.5 \ kN/m^2$ (H.P.)

For Lower Cone. $t_s = 200 \ mm$





For Upper Cone. S_1

$t_s = 100\ mm$

$F.C. = 0.5\ kN/m^2$

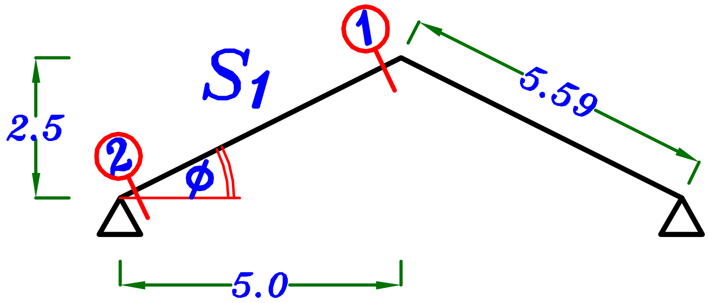
$L.L. = 0.5\ kN/m^2$ (H.P.)

$g_s = t_s\,\gamma_c + F.C.$

$= 0.10 * 25 + 0.50 = 3.0\ kN/m^2$

$p_s = 0.5\ kN/m^2$

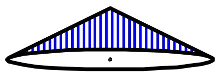
$\tan\phi = \dfrac{2.5}{5.0} \longrightarrow \boxed{\phi = 26.57^\circ}$

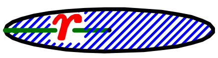


$R_1 = \infty$

Sec. 1 Cone Vertex $(T_1)_1 = (T_2)_1 = Zero$

Sec. 2 $r = 5.0\ m$

$S.A. = \pi * r * L = \pi * 5.0 * 5.59 = 87.80\ m^2$ 

Projected area $= \pi * r^2$  $= \pi * 5.0^2 = 78.54\ m^2$

$W_\phi = g * S.A. + p * \text{Projected area}$

$= 3.0 * 87.80 + 0.5 * 78.54 = +302.67\ kN$

$(T_1)_2 = \dfrac{W_\phi}{2\pi r\ \sin\phi} = \dfrac{+302.67}{2\pi * 5.0 * \sin 26.57^\circ} = +21.49\ kN/m$ Comp.

$Z = g \cos\phi + p \cos^2\phi = 3.0 * \cos 26.57 + 0.5 * \cos^2 26.57 = +3.08\ kN/m^2$

$R_2 = \dfrac{r}{\sin\phi} = \dfrac{5.0}{\sin 26.57^\circ} = 11.18\ m$

$(T_2)_2 = Z * R_2 = 3.08 * 11.18 = +34.43\ kN/m$ Comp.

For beams B_1 & B_2 $\quad L = \frac{2\pi r}{n} = \frac{2*\pi*5.0}{8} = 3.93\ m$

$t = \frac{L}{12} + 0.2\ m = \frac{3.93}{12} + 0.2 = 0.52 = 0.55\ m$

Take B_1 & B_2 (250*550)

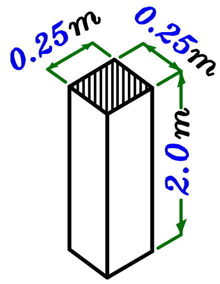
$o.w.(B_1)_{HL\&VL} = 7.0$ kN/m U.L. $= 5.0$ kN/m working

$o.w.(B_2) = b*t*\gamma_c = 0.25*0.55*25 = 3.43$ kN/m

$T.W. =$ Total Weight $(B_1) = o.w.*2\pi r = 5.0*2\pi*5.0 = 157.08$ kN

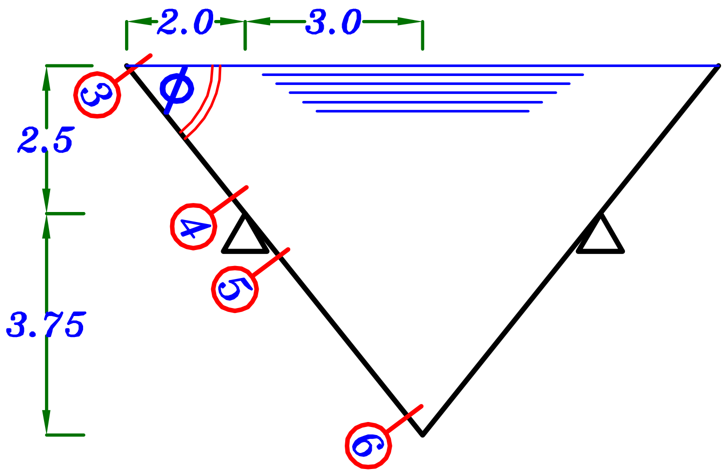
$T.W. =$ Total Weight $(B_2) = o.w.*2\pi r = 3.43*2\pi*5.0 = 107.75$ kN

Take Post (0.25*0.25*2.0)



$o.w.(Post) = 0.25*0.25*2.0*25 = 3.125$ kN

For Lower Cone. S_2



$t_s = 200$ mm

$\gamma_w = 10\ kN/m^3$

$g_s = t_s\,\gamma_c$

$= 0.20*25 = 5.0\ kN/m^2$

$\tan\phi = \frac{2.5}{2.0} \longrightarrow \boxed{\phi = 51.34^\circ}$

$R_1 = \infty$

Sec. 3 $\quad r = 5.0\ m$

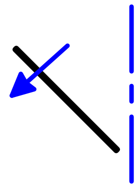
$W_\phi = W_\phi(Sec.2) + T.W.(B_1) + T.W.(B_2) + \underbrace{n}_{\text{number of posts}} * o.w.(Post)$

$W_\phi = 302.67 + 157.08 + 107.75 + 8*3.125 = +592.5$ kN

$$(T_1)_3 = \frac{W_\phi}{2\pi r \ Sin\phi} = \frac{+592.5}{2\pi * 5.0 * Sin\ 51.34^\circ} = +\ 24.15\ kN/m\ Comp.$$

$$Z = g\ Cos\ \phi + \gamma_w * h = 5.0 * Cos\ 51.34 + Zero = -3.12\ \ kN/m^2$$

اشاره Z $(-Ve)$ لان اتجاهها خارج من المحور

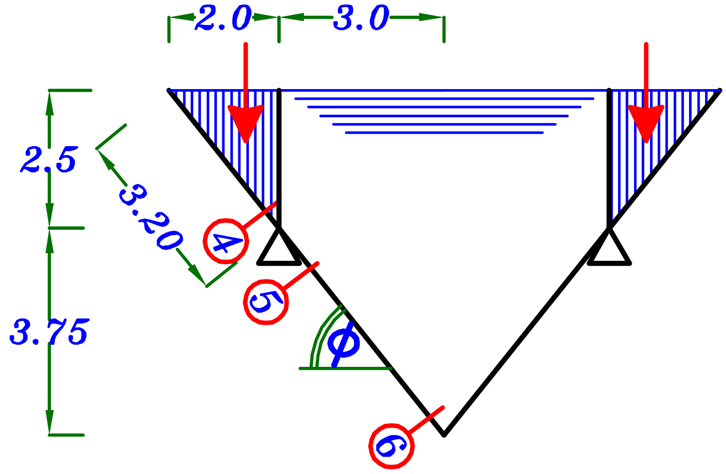


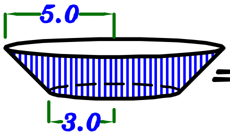
$$R_2 = \frac{r}{Sin\phi} = \frac{5.0}{Sin\ 51.34^\circ} = 6.40\ m$$

$$\because\ (T_2)_3 = Z * R_2 = -3.12 * 6.40 = -\ 19.97\ kN/m\ Ten.$$

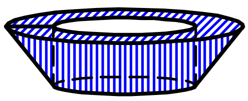
Sec. 4

$r = 3.0\ m$

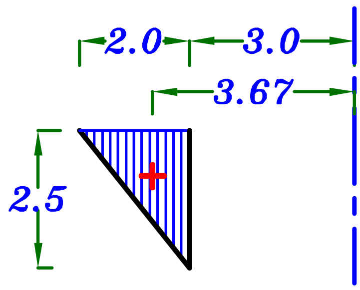


$S.A. = \pi * L\ (a+b)$ 

$= \pi * 3.20 * (5.0 + 3.0) = 80.42\ m^2$

$Volume =$  $= Area * 2\pi * R_{C.G.}$

$$= \left(\frac{1}{2} * 2 * 2.5\right) * 2\pi * \left(3 + \frac{2}{3}\right) = 57.59\,m^3$$



$$W_\phi = W_{\phi\,(Sec.3)} + g * S.A. + \gamma_w * Volume\ \ of\ \ Water$$

$$= 592.5 + 5.0 * 80.42 + 10 * 57.59 = +1570.5\ kN$$

$$(T_1)_4 = \frac{W_\phi}{2\pi r \ Sin\phi} = \frac{+1570.5}{2\pi * 3.0 * Sin\ 51.34^\circ} = +\ 106.7\ kN/m\ Comp.$$

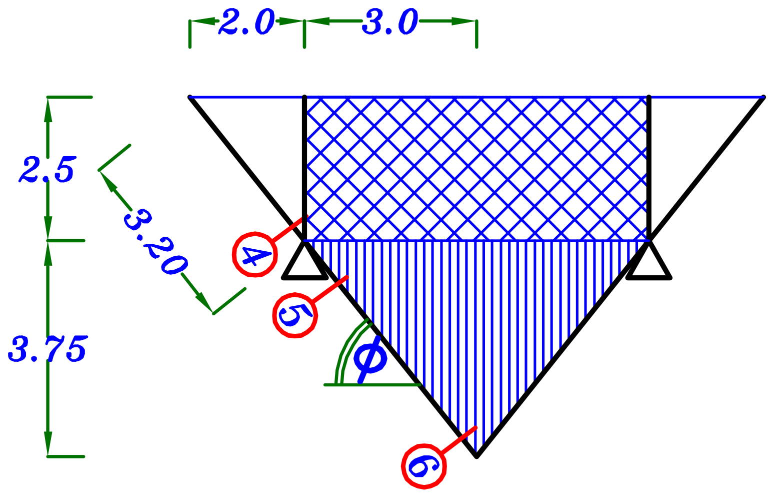
$$Z = g\ Cos\phi + \gamma_w * h = 5.0 * Cos\ 51.34 + 10 * 2.5 = -28.12\ \ kN/m^2$$

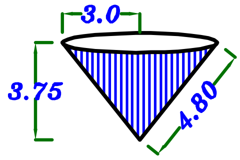
اشاره Z $(-Ve)$ لان اتجاهها خارج من المحور

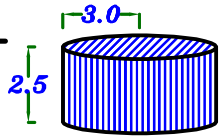
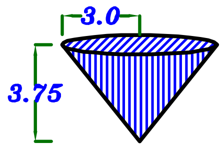
$$R_2 = \frac{r}{Sin\phi} = \frac{3.0}{Sin\ 51.34^\circ} = 3.84\ m$$

$$\because\ (T_2)_4 = Z * R_2 = -28.12 * 3.84 = -\ 108.0\ kN/m\ Ten.$$

Sec. ⑤ $r = 3.0\ m$



$S.A. = \pi * L * r$  $= \pi * 4.80 * 3.0 = 45.24\ m^2$

$Volume = \Big[$  $\pi r^2 * h +$  $\frac{1}{3} * \pi * r^2 * h \Big]$

$$= \pi * 3.0^2 * 2.5 + \frac{1}{3} * \pi * 3.0^2 * 3.75 = 106.03\ m^3$$

$$W_\phi = g * S.A. + \gamma_w * Volume\ of\ Water$$

$$= 5.0 * 45.24 + 10 * 106.03 = -1286.5\ kN$$

اشاره W_ϕ $(-Ve)$ لان اتجاهها خارج من ال Support

$$(T_1)_5 = \frac{W_\phi}{2\pi r\ Sin\phi} = \frac{-1286.5}{2\pi * 3.0 * Sin\ 51.34^\circ} = -87.40\ kN/m\ Ten.$$

$$Z = g\ Cos\phi + \gamma_w * h = 5.0 * Cos\ 51.34 + 10 * 2.5 = -28.12\ kN/m^2$$

اشاره Z $(-Ve)$ لان اتجاهها خارج من المحور

$$R_2 = \frac{r}{Sin\phi} = \frac{3.0}{Sin\ 51.34^\circ} = 3.84\ m$$

$$\because\ (T_2)_5 = Z * R_2 = -28.12 * 3.84 = -108.0\ kN/m\ Ten.$$

Sec. ⑥ Cone Vertex $(T_1)_6 = (T_2)_6 = Zero$

Design of Sections.

For the upper Cone. Sec. 1 & Sec. 2

$(T_{max}) = 34.43$ kN/m Comp.

$$\text{Actual Stress} = \frac{T_{max}}{A_c} = \frac{T_{max}}{1000 * t_s} = \frac{34.43 * 10^3}{1000 * 100} = 0.344 \ N/mm^2$$

$$F_{cu} = 25 \ N/mm^2 \longrightarrow F_{co} = 6.0 \ N/mm^2$$

$$\text{Allawable Stress} = \frac{F_{co}}{2} = \frac{6.0}{2} = 3.0 \ N/mm^2$$

Actual Stress < Allawable Stress $\longrightarrow$ $t_s = 100$ mm is o.k.

To Get T_1 RFT. $\longrightarrow$ No Tension $\xrightarrow{\text{use min. RFT.}}$ $5 \phi 10 \backslash m'$ each Side

To Get T_2 RFT. $\longrightarrow$ No Tension $\xrightarrow{\text{use min. RFT.}}$ $5 \phi 10 \backslash m'$ each Side

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For the lower Cone. Sec. 3, Sec. 4, Sec. 5 & Sec. 6

Check Compression Stresses.

$(T_{max}) = 106.7$ kN/m Comp.

$$\text{Actual Stress} = \frac{T_{max}}{A_c} = \frac{T_{max}}{1000 * t_s} = \frac{106.7 * 10^3}{1000 * 200} = 0.533 \ N/mm^2$$

$$F_{cu} = 25 \ N/mm^2 \longrightarrow F_{co} = 6.0 \ N/mm^2$$

$$\text{Allawable Stress} = \frac{F_{co}}{2} = \frac{6.0}{2} = 3.0 \ N/mm^2$$

Actual Stress < Allawable Stress $\longrightarrow$ $t_s = 200$ mm is o.k.

Check Tension Stresses.

$(T_{max}) = 108.0$ kN/m Ten.

$$\text{Actual Stress} = \frac{T_{max}}{A_c} = \frac{T_{max}}{1000 * t_s} = \frac{108.0 * 10^3}{1000 * 200} = 0.54 \ N/mm^2$$

$$\text{Allawable Stress} = \frac{F_{ctr}}{\eta} = \frac{0.6\sqrt{F_{cu}}}{1.7} = \frac{0.6\sqrt{25}}{1.7} = 1.764 \ N/mm^2$$

Actual Stress < Allawable Stress $\longrightarrow$ $t_s = 200$ mm is o.k.

To Get T_1 RFT. $\longrightarrow$ max. Tension $T_1 = 87.40$ kN/m

$$As_{(T_1)} = \frac{T_{1\,(U.L.)}}{F_y \backslash \gamma_s} = \frac{1.5*87.40*10^3}{360\backslash 1.15} = 418.8 \ mm^2/m$$

$$As_{(T_1)}\backslash Side = \frac{418.8}{2} = 209.4 \ mm^2/m \xrightarrow{\text{use min. RFT.}} 5\phi 10\backslash m' \text{ each Side}$$

To Get T_2 RFT. $\longrightarrow$ max. Tension $T_2 = 108.0$ kN/m

$$As_{(T_2)} = \frac{T_{2\,(U.L.)}}{F_y \backslash \gamma_s} = \frac{1.5*108.0*10^3}{360\backslash 1.15} = 517.5 \ mm^2/m$$

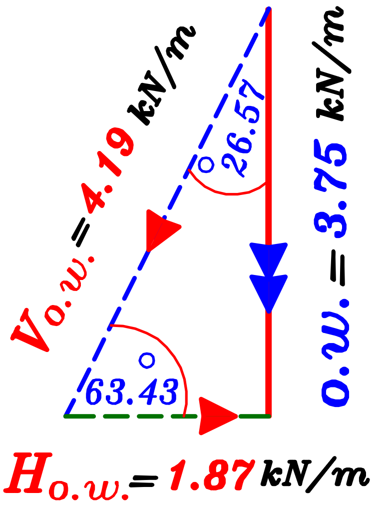
$$As_{(T_2)}\backslash Side = \frac{517.5}{2} = 258.7 \ mm^2/m \xrightarrow{\text{use min. RFT.}} 5\phi 10\backslash m' \text{ each Side}$$

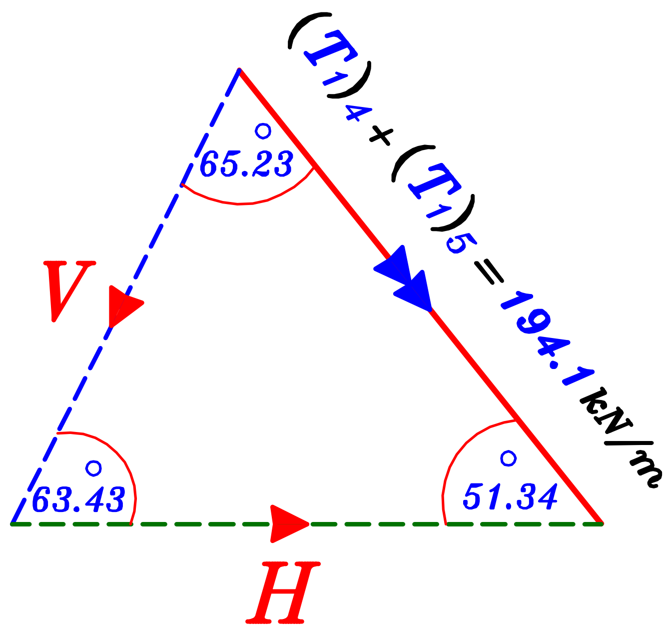
Design of Beam B3

Take $b = 300$ mm $\qquad L = \frac{2\pi r}{n} = \frac{2*\pi*3}{6} = 3.14$ m

$t = \frac{L}{12} + 0.2\,m = \frac{3.14}{12} + 0.2 = 0.46 = 0.50$ m Take $(300*500)$

$$o.w._{(B_3)} = b*t*\gamma_c = 0.30*0.50*25 = 3.75 \ kN/m$$

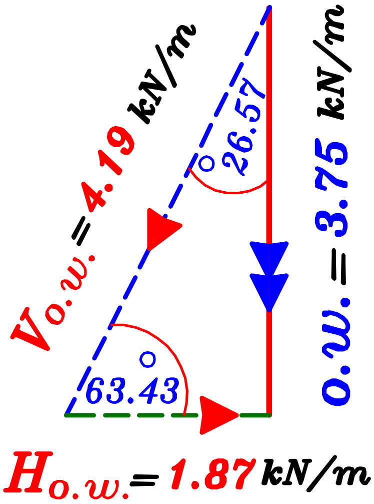


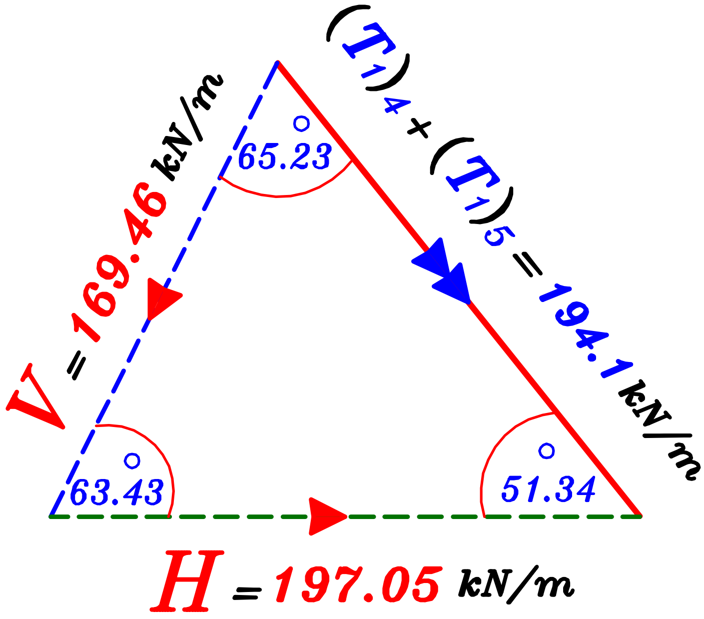


Use Sin Rule.

$$\frac{194.1}{Sin\ 63.43} = \frac{V}{Sin\ 51.34} = \frac{H}{Sin\ 65.23} \longrightarrow V = 169.46 \ kN/m$$

$$H = 197.05 \ kN/m$$





$$w_{(Beam)} = V_{o.w.} + V = 4.19 + 169.46 = 173.65 \ kN/m$$

$$H_{(Beam)} = H_{o.w.} + H = 1.87 + 197.05 = 198.92 \ kN/m$$ للداخل

$$\text{Compression Force on Beam} = H * r$$

$$= 198.92 * 3.0 = 596.76 \ kN$$

From Tables $n = 6.0$

No. of supports	Load on each support	Max. Shearing Force	Max. Bending Moment at C.L. of Span	Max. Bending Moment Over C.L. of Column	Max. Torsional Moment	Central angle
n	R	$Q_{max.}$	M +Ve	M −Ve	$M_{t\,max.}$	θ
4	P/4	P/8	0.0176 Pr	− 0.0322 Pr	0.0053 Pr	19° 21`
6	**P/6**	**P/12**	**0.0075 Pr**	**− 0.0148 Pr**	**0.0015 Pr**	**12° 44`**
8	P/8	P/16	0.0042 Pr	− 0.0083 Pr	0.0006 Pr	9° 33`
10	P/10	P/20	0.0032 Pr	− 0.0052 Pr	0.0004 Pr	7° 36`
12	P/12	P/24	0.0019 Pr	− 0.0037 Pr	0.0002 Pr	6° 21`

$$P = w * 2\pi r = 173.65 * 2\pi * 3.0 = 3273.22 \ kN$$

$max.\ M_{+Ve} = 0.0075\ P r = 0.0075 * 3273.22 * 3.0 = 73.65$ kN.m

$max.\ M_{-Ve} = 0.0148\ P r = 0.0148 * 3273.22 * 3.0 = 145.33$ kN.m

$max.\ M_t = 0.0015\ P r = 0.0015 * 3273.22 * 3.0 = 14.73$ kN.m

$$Q_{max.} = \frac{P}{12} = \frac{3273.22}{12} = 272.77 \text{ kN}$$

Centeral angel $\theta = 12^{\circ}\ 44' = 12.73^{\circ}$

$$X = r * \theta * \frac{\pi}{180} = 3.0 * 12.73 * \frac{\pi}{180} = 0.66 \text{ m}$$

$$Q_{cor.} = Q_{max} - w * X = 272.77 - 173.65 * 0.66 = 158.16 \text{ kN}$$

Design beam B3 on M & P

$b = 300$ mm , $t = 500$ mm

Sec. of max. $-Ve$ B.M.

$M = 145.33 * 1.5 = 218.0$ kN.m. , $P = 596.76 * 1.5 = 895.14$ kN

$$\text{Check } \frac{P}{F_{cu}\, b\, t} = \frac{895.14 * 10^3}{25 * 300 * 500} = 0.238 > 0.04 \quad (\text{Don't Neglect } P)$$

$$e = \frac{M}{P} = \frac{218.0}{895.14} = 0.243 \text{ m}$$

$$\therefore \frac{e}{t} = \frac{0.243}{0.50} = 0.48 < 0.5 \xrightarrow{Use} \text{I.D.}$$

$$\zeta = \frac{500 - 100}{500} = 0.80 \xrightarrow{use} \text{ECCS Design Aids Page 4-24}$$

$$\left.\begin{array}{l} \dfrac{P}{F_{cu}\, b\, t} = \dfrac{895.14 * 10^3}{25 * 300 * 500} = 0.24 \\[2ex] \dfrac{M}{F_{cu}\, b\, t^2} = \dfrac{218.0 * 10^6}{25 * 300 * 500^2} = 0.11 \end{array}\right\} \rho = 2.40$$

$$\mu = \rho * F_{cu} * 10^{-4} = 2.4 * 25 * 10^{-4} = 6.0 * 10^{-3}$$

$$As = As' = \mu * b * t = 6.0 * 10^{-3} * 300 * 500 = 900 \ mm^2$$

$$As_{Total} = As + As' = 2 * 900 = 1800 \ mm^2$$

Check $$As_{min.} = \frac{0.8}{100} * b * t = \frac{0.8}{100} * 300 * 500 = 1200 mm^2$$

$$\therefore As_{Total} > As_{min.} \quad \therefore As = As' = 900 \ mm^2$$

Sec. of max. +Ve B.M.

$$M = 73.65 * 1.5 = 110.47 \ kN.m. \quad , \quad P = 596.76 * 1.5 = 895.14 \ kN$$

Check $$\frac{P}{F_{cu} \, b \, t} = \frac{895.14 * 10^3}{25 * 300 * 500} = 0.238 > 0.04$$ (**Don't Neglect P**)

$$e = \frac{M}{P} = \frac{110.47}{895.14} = 0.123 \ m$$

$$\therefore \frac{e}{t} = \frac{0.123}{0.50} = 0.246 < 0.5 \xrightarrow{Use} I.D.$$

$$\zeta = \frac{500 - 100}{500} = 0.80 \xrightarrow{use}$$ ECCS Design Aids Page 4–24

$$\left. \begin{aligned} \frac{P}{F_{cu} \, b \, t} &= \frac{895.14 * 10^3}{25 * 300 * 500} = 0.24 \\ \frac{M}{F_{cu} \, b \, t^2} &= \frac{110.47 * 10^6}{25 * 300 * 500^2} = 0.058 \end{aligned} \right\} \rho = 1.0$$

$$\mu = \rho * F_{cu} * 10^{-4} = 1.0 * 25 * 10^{-4} = 2.5 * 10^{-3}$$

$$As = As' = \mu * b * t = 2.5 * 10^{-3} * 300 * 500 = 375 \ mm^2$$

$$As_{Total} = As + As' = 2 * 375 = 750 \ mm^2$$

Check $$As_{min.} = \frac{0.8}{100} * b * t = \frac{0.8}{100} * 300 * 500 = 1200 \ mm^2$$

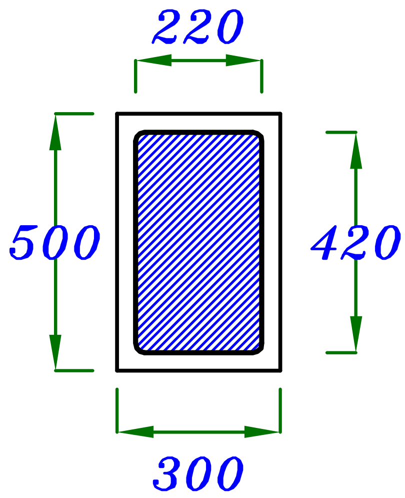
$$\therefore As_{Total} < As_{min.}$$

$$\therefore As = As' = \frac{As_{min.}}{2} = \frac{1200}{2} = 600 \ mm^2$$

Design due to Shear & Torsion.

$b = 300\ mm\ ,\ t = 500\ mm$

$$q_u = \frac{Q}{b\,d} = \frac{1.5 * 158.16 * 10^3}{300 * 450} = 1.757\ N/mm^2$$



$$A_{oh} = 220 * 420 = 92400\ mm^2$$

$$A_o = 0.85 * A_{oh} = 0.85 * 92400 = 78540\ mm^2$$

$$P_h = 2 * 220 + 2 * 420 = 1280\ mm$$

$$t_e = \frac{A_{oh}}{P_h} = \frac{92400}{1280} = 72.18\ mm$$

$$q_{tu} = \frac{M_{tu}}{2\,A_o\,t_e} = \frac{1.5 * 14.73 * 10^6}{2 * 78540 * 72.18} = 1.948\ N/mm^2$$

$$q_{cu} = (0.24)\sqrt{\frac{25}{1.5}} = 0.98\ N/mm^2$$

$$q_{t\,min} = (0.06)\sqrt{\frac{25}{1.5}} = 0.245\ N/mm^2$$

$$q_{u\,max} = (0.7)\sqrt{\frac{25}{1.5}} = 2.85\ N/mm^2$$

$$\sqrt{q_u^2 + q_{tu}^2} = \sqrt{1.757^2 + 1.948^2} = 2.623\ N/mm^2 < q_{u\,max}\ \therefore\ o.k.$$

$\boxed{q_u > q_{cu}\ ,\ q_{tu} > q_{t\,min}}$ $\therefore$ Use RFT. For Shear & Torsion

For Torsion

$$\therefore A_{str} = \frac{M_{tu}\ S_t}{(1.7)\ A_{oh}\ \left(\frac{F_y}{\gamma_s}\right)} \qquad \therefore A_{str} = \frac{(1.5 * 14.73 * 10^6) * S_t}{(1.7)(92400)(240/1.15)}$$

$$\therefore \boxed{A_{str} = 0.674 * S_t}$$

For Shear.

$$q_u - \frac{q_{cu}}{2} = \frac{n A_s (F_y \backslash \gamma_s)}{b\ S_s} \qquad \therefore 1.757 - \frac{0.98}{2} = \frac{n A_s\ (240/1.15)}{(300)\ S_s}$$

$$\therefore \boxed{A_s = 1.821 \frac{S_s}{n}}$$

Choose $n = 2$, $S = 8/m' \longrightarrow S = \frac{1000}{8} = 125$ mm

$$\therefore A_{str} = 0.674 * S_t = 0.674 * 125 = 84.25\ mm^2$$

$$A_s = 1.821 \frac{S_s}{n} = 1.821 * \frac{125}{2} = 113.81\ mm^2$$

$$A_{str} + A_s = 84.25 + 113.81 = 198.06\ mm^2 > \phi 12$$

wrong assumption

Choose $n = 4$, $S = 10/m' \longrightarrow S = \frac{1000}{10} = 100$ mm

$$\therefore A_{str} = 0.674 * S_t = 0.674 * 100 = 67.4\ mm^2$$

$$A_s = 1.821 \frac{S_s}{n} = 1.821 * \frac{100}{4} = 45.52\ mm^2$$

For Outer Stirrups

$$A_{str} + A_s = 67.4 + 45.52 = 112.92\ mm^2 \xrightarrow{use} \phi 12 = 113\ mm^2$$

For Inner Stirrups

$$A_s = 45.52\ mm^2 \xrightarrow{use} \phi 8 = 50.3\ mm^2$$

Use Outer Closed Stirrups $\boxed{10 \phi 12 \backslash m}$

Use Inner Stirrups $\boxed{10 \phi 8 \backslash m}$

* Longitudinal Bars.

$$S_t = \frac{1000}{10} = 100 \ mm$$

$$A_{sl} = \frac{A_{str} * P_h}{S_t} \left(\frac{F_{y\,str.}}{F_{y\,L.b.}}\right) = \frac{(67.4 * 1280)}{100}\left(\frac{240}{360}\right) = 575.14 \ mm^2$$

$$\therefore \frac{A_{sl}}{4} = \frac{575.14}{4} = 143.78 \ mm^2$$

$$A_{s\,-Ve} = A_s + \frac{A_{sl}}{4} = 900 + 143.78 = 1043.78 \ mm^2$$

$6 \phi 16$

$$\therefore n = \frac{b - 25}{\phi + 25} = \frac{300 - 25}{16 + 25} = 6.70 = 6.0$$

$$A_{s\,+Ve} = A_s + \frac{A_{sl}}{4} = 600 + 143.78 = 743.78 \ mm^2$$

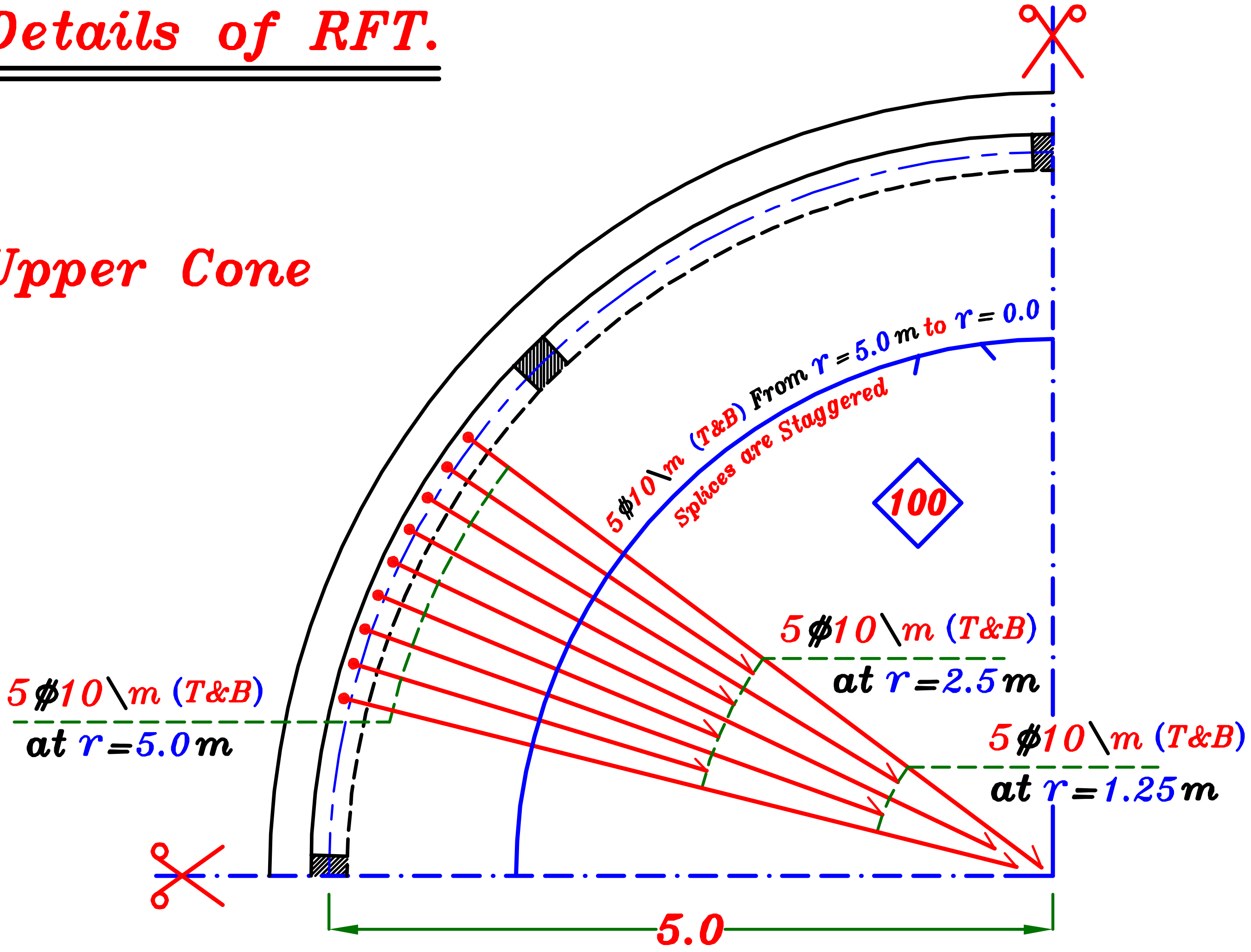
$4 \phi 16$

$$\text{Stirrup Hangers} = \frac{A_s}{10} + \frac{A_{sl}}{4} = \frac{743.78}{10} + 143.78 = 218.16 \ mm^2$$

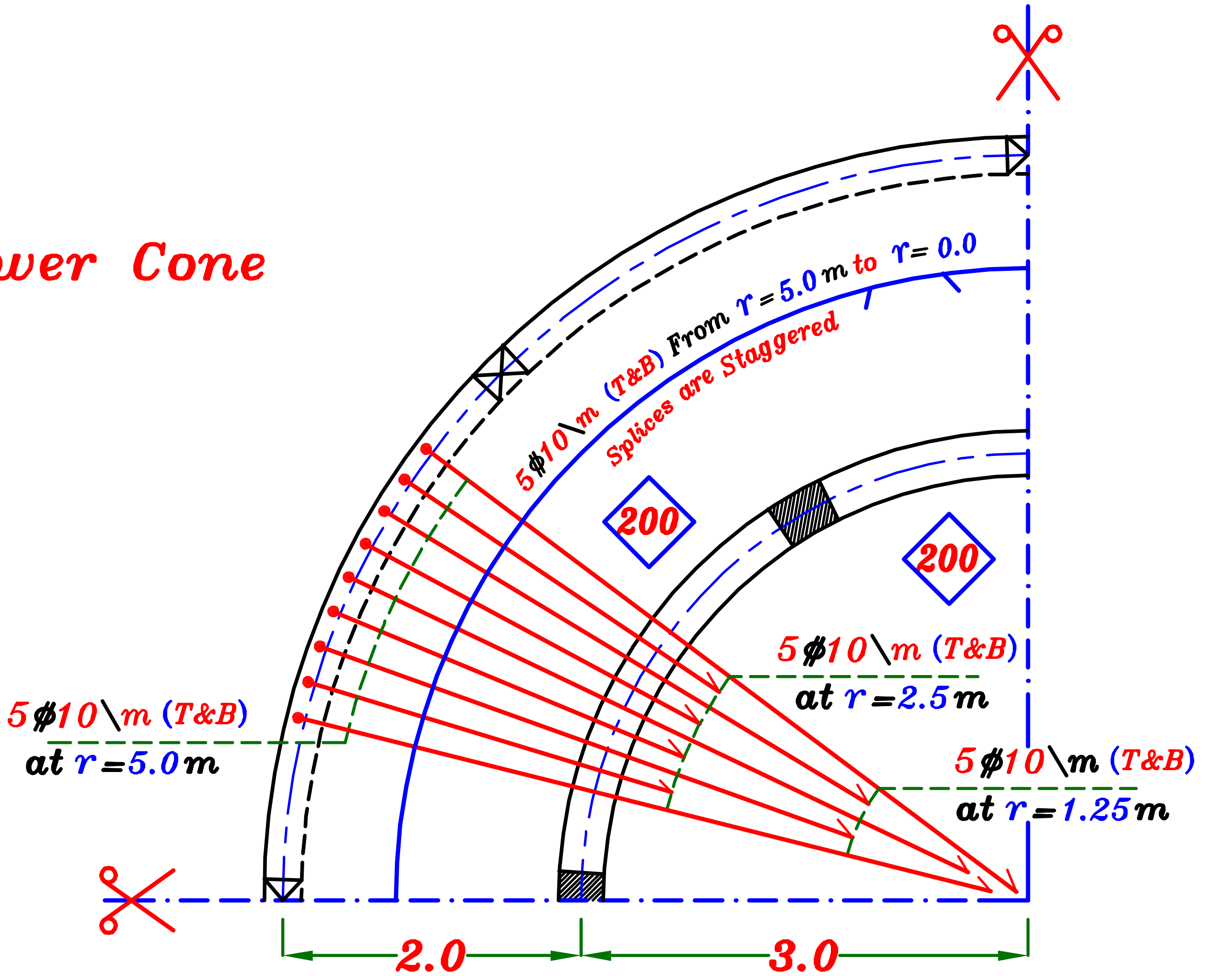
$2 \phi 12$

Details of RFT.

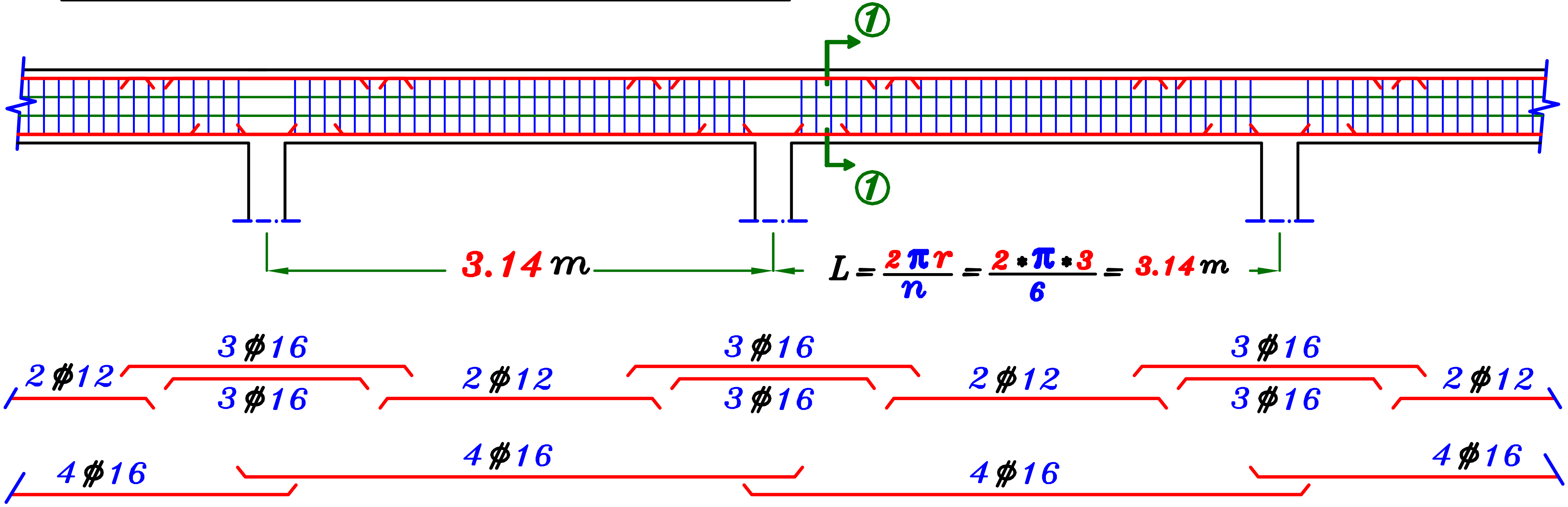
Upper Cone

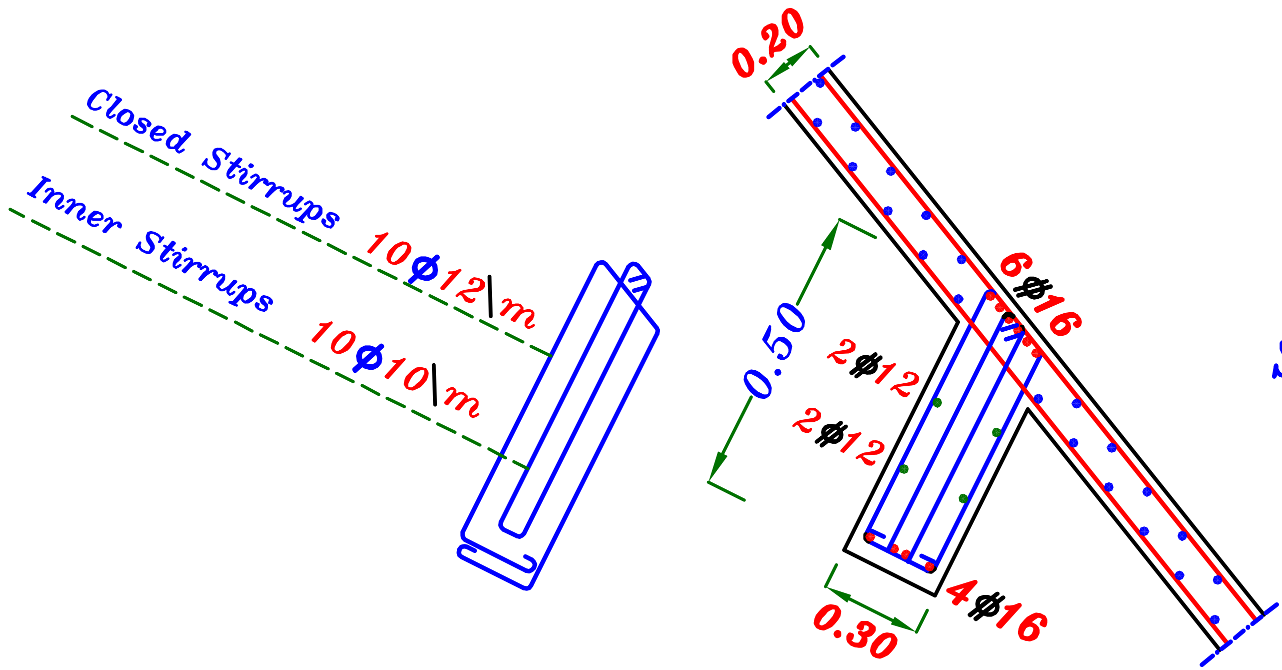


Lower Cone



Developed Elevation of Beam B_3





Sec. (1–1)

Example.

For the shown surface of revolution, It is required to:

1- Calculate the internal Forces at the critical sections.

2- Design the surface of revolution and draw details of RFT. in plan and cross sections.

3- Design the beam B_2 and draw their details of RFT. in Cross Section.

Given:

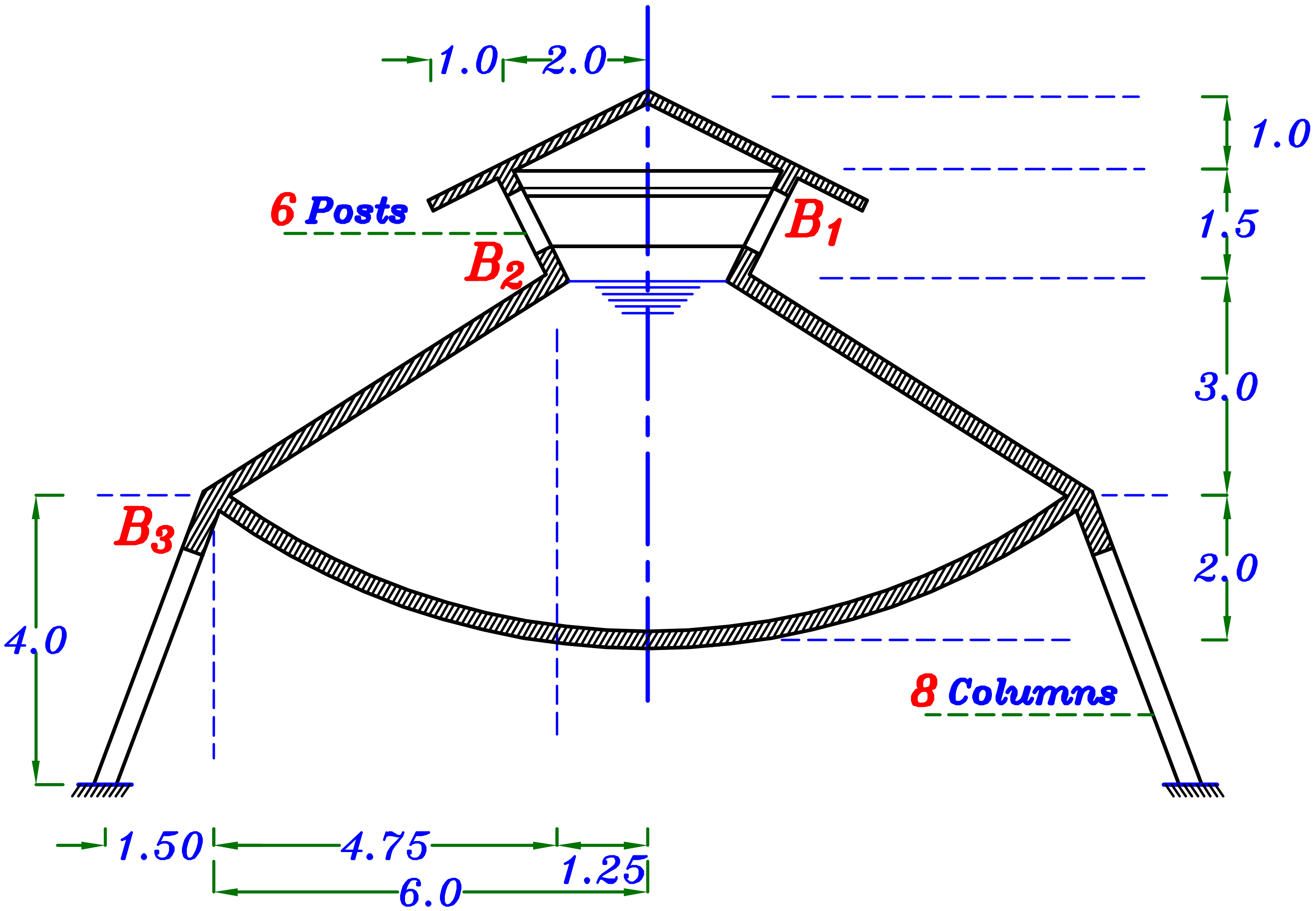
$F_{cu} = 25$ N/mm^2 , st. 360/520

For Upper Cone.

$t_s = 100$ mm , F.C. = 0.50 kN/m^2 , L.L. = 0.50 kN/m^2 (H.P.)

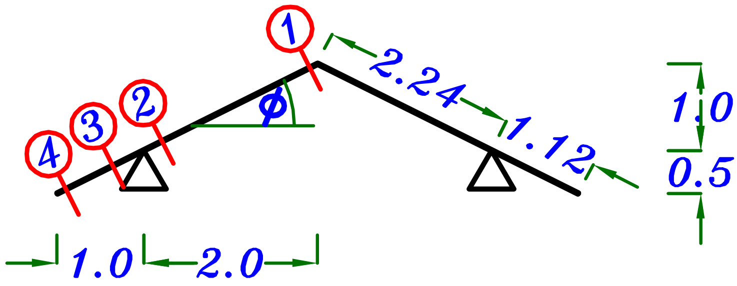
For Lower Cone & Lower Dome.

$t_s = 200$ mm , F.C. = 0.50 kN/m^2



Solution.

For Upper Cone.



$t_s = 100\ mm$

$F.C. = 0.50\ kN/m^2$

$L.L. = 0.50\ kN/m^2\ (H.P.)$

$g_s = t_s\,\gamma_c + F.C. = 0.10 * 25 + 0.50 = 3.0\ kN/m^2$

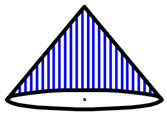
$p_s = 0.5\ kN/m^2$

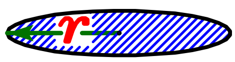
$\tan\phi = \dfrac{1.0}{2.0} \longrightarrow \boxed{\phi = 26.56^\circ}$

$R_1 = \infty$

Sec. 1 Cone Vertex $(T_1)_1 = (T_2)_1 = Zero$

Sec. 2 $r = 2.0\ m$

$S.A. = \pi * r * L = \pi * 2.0 * 2.24 = 14.07\ m^2$ 

Projected area $= \pi * r^2$ 

$= \pi * 2.0^2 = 12.56\ m^2$

$W_\phi = g * S.A. + p * \text{Projected area}$

$= 3.0 * 14.07 + 0.5 * 12.56 = +48.49\ kN$

$(T_1)_2 = \dfrac{W_\phi}{2\pi r\ \sin\phi} = \dfrac{+48.49}{2\pi * 2.0 * \sin 26.56^\circ} = +8.63\ kN/m$ Comp.

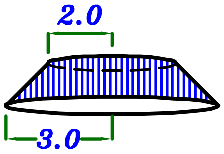
$Z = g\cos\phi + p\cos^2\phi = 3.0 * \cos 26.56 + 0.5 * \cos^2 26.56 = +3.08\ kN/m^2$

$R_2 = \dfrac{r}{\sin\phi} = \dfrac{2.0}{\sin 26.56^\circ} = 4.47\ m$

$(T_2)_2 = Z * R_2 = 3.08 * 4.47 = +13.76\ kN/m$ Comp.

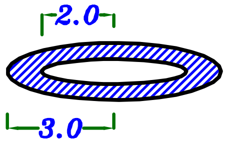
Sec. ③ $\quad r = 2.0\ m$

$$S.A. = \pi * L\,(a+b)$$



$$= \pi * 1.12 * (3.0 + 2.0) = 17.59 \quad m^2$$

$$\text{Projected area} = \pi * (r_1^2 - r_2^2)$$



$$= \pi * (3.0^2 - 2.0^2) = 15.71 \quad m^2$$

$$W_\phi = g * S.A. + p * \text{Projected area}$$

$$= 3.0 * 17.59 + 0.5 * 15.71 = -60.62\ kN$$

اشاره W_ϕ $(-Ve)$ لان اتجاهها خارج من ال Support

$$(T_1)_3 = \frac{W_\phi}{2\pi r\ \sin\phi} = \frac{-60.62}{2\pi * 2.0 * \sin 26.56^\circ} = -\ 10.79\ kN/m \quad \text{Ten.}$$

$$Z = g\cos\phi + p\cos^2\phi = 3.0 * \cos 26.56 + 0.5 * \cos^2 26.56 = +3.08\ kN/m^2$$

$$R_2 = \frac{r}{\sin\phi} = \frac{2.0}{\sin 26.56^\circ} = 4.47\ m$$

$$(T_2)_3 = Z * R_2 = 3.08 * 4.47 = +\ 13.76\ kN/m \quad \text{Comp.}$$

Sec. ④ $\quad r = 3.0\ m$

$$W_\phi = Zero \longrightarrow (T_1)_4 = Zero$$

$$Z = g\cos\phi + p\cos^2\phi = 3.0 * \cos 26.56 + 0.5 * \cos^2 26.56 = +3.08\ kN/m^2$$

$$R_2 = \frac{r}{\sin\phi} = \frac{3.0}{\sin 26.56^\circ} = 6.71\,m$$

$$(T_2)_4 = Z * R_2 = 3.08 * 6.71 = +\ 20.66\ kN/m \quad \text{Comp.}$$

For beams B_1 $L = \frac{2\pi r}{n} = \frac{2*\pi*2}{6} = 2.09\ m$

$t = \frac{L}{12} + 0.2\ m = \frac{2.09}{12} + 0.2 = 0.37 = 0.40\ m$

Take B_1 (250*400)

$o.w._{(B_1)} = b*t*\gamma_c = 0.25*0.40*25 = 2.50\ kN/m$

T.W. = Total Weight $(B_1) = o.w.*2\pi r = 2.50*2\pi*2.0 = 31.41\ kN$

For beams B_2 $L = \frac{2\pi r}{n} = \frac{2*\pi*1.25}{6} = 1.31\ m$

$t = \frac{L}{12} + 0.2\ m = \frac{1.31}{12} + 0.2 = 0.31 = 0.40\ m$

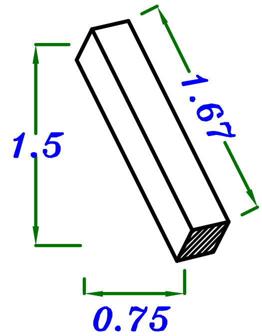
Take B_2 (250*400)

$o.w._{(B_2)} = b*t*\gamma_c = 0.25*0.40*25 = 2.50\ kN/m$

T.W. = Total Weight $(B_2) = o.w.*2\pi r = 2.50*2\pi*1.25 = 19.63\ kN$

Take Post (0.25*0.25*1.67)

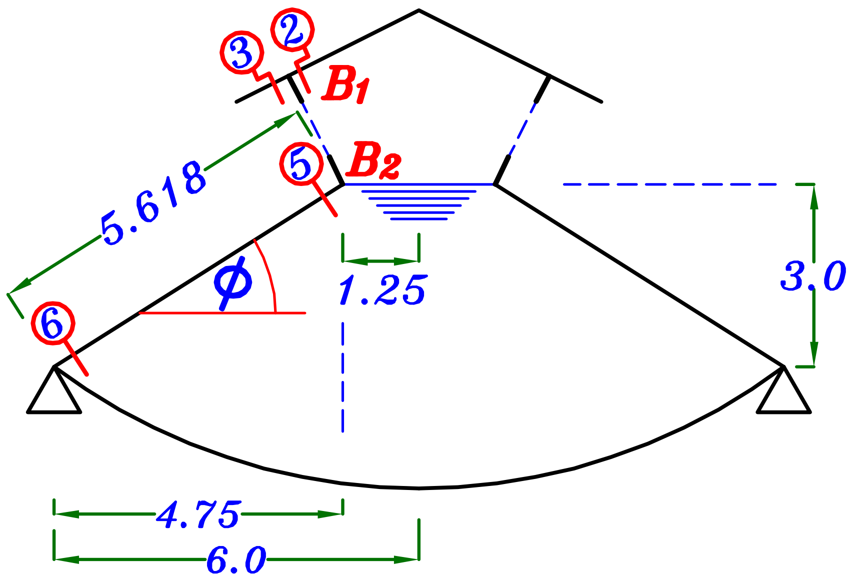
$o.w._{(Post)} = 0.25*0.25*1.67*25 = 2.61\ kN$



For Lower Cone.

$\tan\phi = \frac{3.0}{4.75}$

$\rightarrow \boxed{\phi = 32.27^\circ}$



$t_s = 200\ mm \quad F.C. = 0.50\ kN/m^2$

$g_s = t_s\,\gamma_c + F.C. = 0.20*25 + 0.50 = 5.50\ kN/m^2$

Sec. ⑤ $r = 1.25\ m$

$$W_\phi = W_{\phi\,(Sec.2)} + W_{\phi\,(Sec.3)} + T.W._{(B_1)} + T.W._{(B_2)} + \underbrace{n}_{\text{number of posts}} * o.w._{(Post)}$$

$$W_\phi = 48.49 + 60.62 + 31.41 + 19.63 + 6 * 2.61 = +175.81\ kN$$

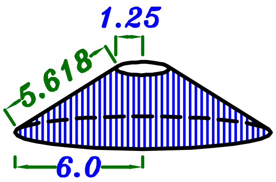
$$(T_1)_5 = \frac{W_\phi}{2\pi r \sin\phi} = \frac{+175.81}{2\pi * 1.25 * \sin 32.27^\circ} = +41.92\ kN/m\ \text{Comp.}$$

$$Z = g \cos\phi = 5.5 * \cos 32.27 = +4.65\ kN/m^2$$

$$R_2 = \frac{r}{\sin\phi} = \frac{1.25}{\sin 32.27^\circ} = 2.34\ m$$

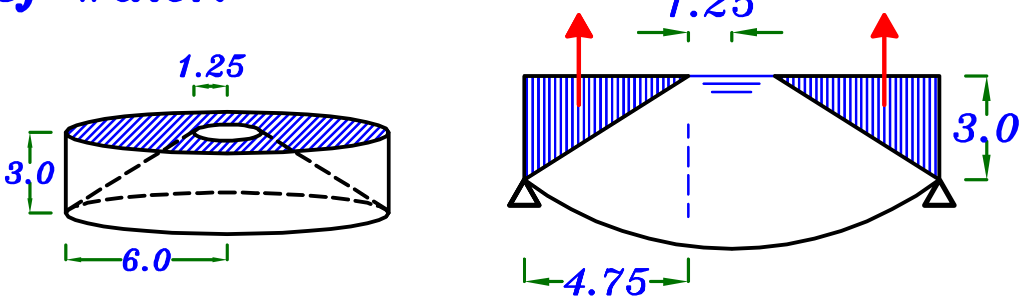
$$(T_2)_5 = Z * R_2 = 4.65 * 2.34 = +10.88\ kN/m\ \text{Comp.}$$

Sec. ⑥ $r = 6.0\ m$

$S.A. = \pi * L\,(a+b)$ 

$= \pi * 5.618\,(6.0 + 1.25) = 127.95\ m^2$

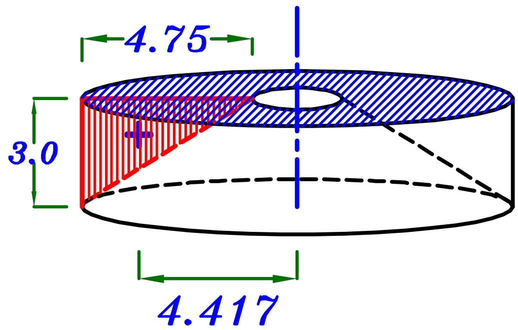
Virtual Volume of Water.



$$\text{Volume} = \text{Area} * 2\pi * R_{C.G.}$$

$$= \left(\frac{1}{2} * 3.0 * 4.75\right) * 2\pi * 4.417$$

$$= 197.74\ m^3$$



$$W_\phi = W_{\phi\,(Sec.5)} \downarrow + g * S.A. \downarrow - \gamma_w * Volume \uparrow$$

$$W_\phi = 175.81 + 5.50 * 127.95 - 10.0 * 197.74 = -1097.86$$

تم طرح القيمتين من بعضهما لان وزن السطح $(g * S.A.)$ يؤثر رأسيا لاسفل

بينما ضغط الماء $(\gamma_w * Volume)$ يؤثر رأسيا لاعلى .

$$(T_1)_6 = \frac{W_\phi}{2\pi r \, Sin\phi} = \frac{-1097.86}{2\pi * 6.0 * Sin\, 32.27^\circ} = -54.54 \ kN/m \ \ Ten.$$

$$Z = g\, Cos\, \phi \searrow - \gamma_w * h \nwarrow$$

$$= 5.5 * Cos\, 32.27^\circ - 10 * 3.0 = -25.35 \ kN/m^2$$

$$R_2 = \frac{r}{Sin\phi} = \frac{6.0}{Sin\, 32.27^\circ} = 11.23 \ m$$

$$\because (T_2)_6 = Z * R_2 = -25.35 * 11.23 = -284.68 \ kN/m \ \ Ten.$$

For Lower Dome.

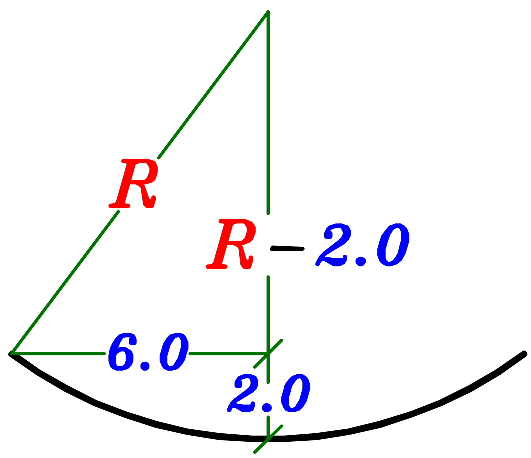
$$t_s = 200 \ mm \qquad F.C. = 0.50 \ kN/m^2$$

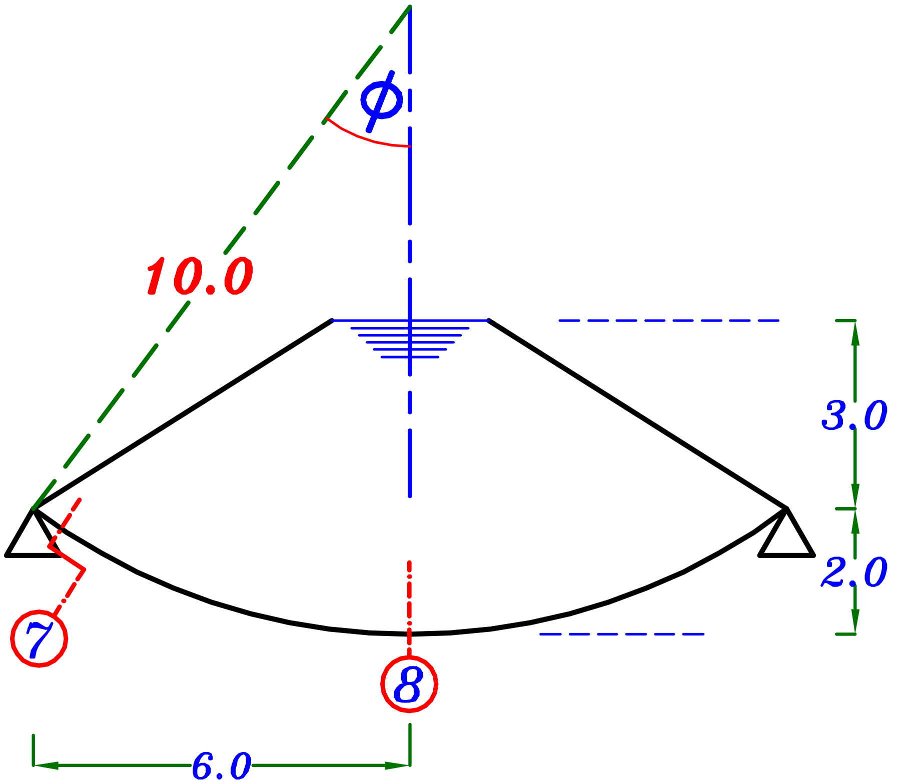
$$g_s = t_s \, \gamma_c + F.C. = 0.20 * 25 + 0.50 = 5.50 \ kN/m^2$$

$$R^2 = 6.0^2 + (R - 2.0)^2$$

$$\cancel{R^2} = 36 + \cancel{R^2} - 4.0\, R + 4.0$$

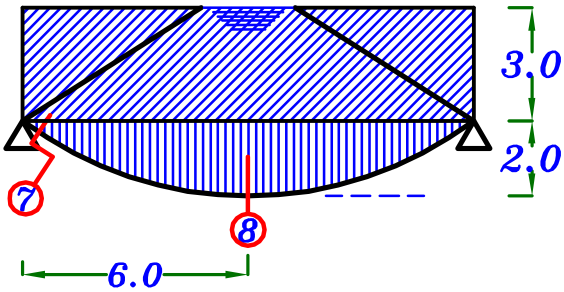
$$4.0\, R = 40.0 \longrightarrow \boxed{R = 10.0\, m}$$



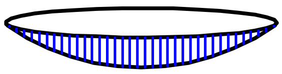


Sec. 7 $\quad r = 6.0\ m$

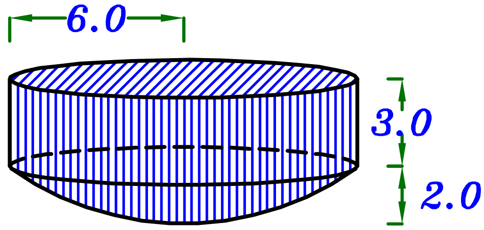
$$\sin\phi = \frac{6.0}{10.0} \rightarrow \boxed{\phi = 36.87^\circ}$$



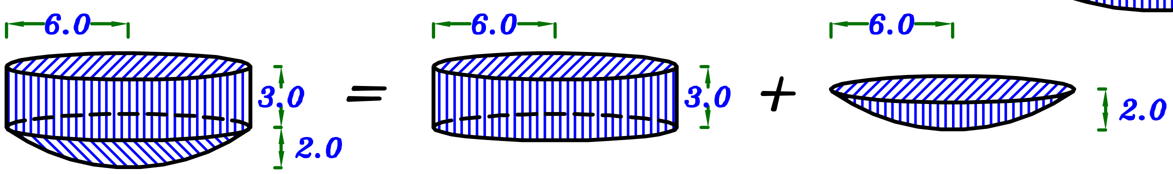
$$S.A. = 2\pi * R * h$$



$$= 2\pi * 10.0 * 2.0 = 125.66\ m^2$$



Volume of water



$$= \pi r^2 * h + \pi * h^2 \left(R - \frac{h}{3}\right)$$

$$= \pi * 6.0^2 * 3.0 + \pi * 2.0^2 * \left(10 - \frac{2.0}{3}\right)$$

$$= 456.58\ m^3$$

$$W_\phi = g * S.A. \downarrow + \gamma_w * Volume \downarrow$$

$$= 5.5 * 125.66 + 10.0 * 456.58 = -5256.93 \ kN$$

اشاره W_ϕ $(-Ve)$ لان اتجاهها خارج من ال Support

$$(T_1)_7 = \frac{W_\phi}{2\pi r \ Sin\phi} = \frac{-5256.93}{2\pi * 6.0 * Sin\ 36.87^\circ} = -\ 232.41 \ \ kN/m \ \ Ten.$$

$$R_1 = R_2 = R = 10.0 \ m$$

$$Z = -g \ Cos\phi \swarrow - \gamma_w * h \swarrow$$

$$= -5.5 * Cos\ 36.87^\circ - 10 * 3.0 = -34.40 \ \ kN/m^2$$

اشاره Z $(-Ve)$ لان اتجاهها خارج من المحور

$$\because \ T_1 + T_2 = Z * R \qquad \therefore \ -232.41 + T_2 = -\ 34.40 * 10.0$$

$$\therefore \ (T_2)_7 = -\ 111.59 \ kN/m \ \ Ten.$$

Sec. 8

Dome Vertex $\phi = Zero$

$$Z = -g \ Cos\phi \downarrow - \gamma_w * h \downarrow$$

$$= -5.5 * Cos\ 0.0 - 10 * 5.0 = -55.50 \ \ kN/m^2$$

$$(T_1)_1 = (T_2)_1 = \frac{RZ}{2} = \frac{10.0 * (-55.5)}{2} = -\ 277.5 \ kN/m \ \ Ten.$$

Design of Sections.

For upper cone. Sec. 1 , Sec. 2 , Sec. 3 & Sec. 4

$(T_{max}) = 20.66$ kN/m Comp.

$$\text{Actual Stress} = \frac{T_{max}}{A_c} = \frac{T_{max}}{1000 * t_s} = \frac{20.66 * 10^3}{1000 * 100} = 0.206 \ N/mm^2$$

$F_{cu} = 25 \ N/mm^2 \longrightarrow F_{co} = 6.0 \ N/mm^2$

$$\text{Allawable Stress} = \frac{F_{co}}{2} = \frac{6.0}{2} = 3.0 \ N/mm^2$$

Actual Stress < Allawable Stress $\longrightarrow t_s = 100$ mm is o.k.

To Get T_1 RFT. $\longrightarrow$ max. Tension $T_1 = 10.79$ kN/m

$$A_{s(T_1)} = \frac{T_{1\,(U.L.)}}{F_y \backslash \delta_s} = \frac{1.5 * 10.79 * 10^3}{360 \backslash 1.15} = 51.70 \ mm^2/m$$

$$A_{s(T_1)} \backslash Side = \frac{51.70}{2} = 25.85 \ mm^2/m \xrightarrow{\text{use min. RFT.}} 5 \phi 10 \backslash m' \text{ each Side}$$

To Get T_2 RFT. $\longrightarrow$ No Tension $\xrightarrow{\text{use min. RFT.}} 5 \phi 10 \backslash m'$ each Side

---

For Lower cone. Sec. 5 & Sec. 6 Water Sections.

Check Compression Stresses.

$(T_{max}) = 41.92$ kN/m Comp.

$$\text{Actual Stress} = \frac{T_{max}}{A_c} = \frac{T_{max}}{1000 * t_s} = \frac{41.92 * 10^3}{1000 * 200} = 0.209 \ N/mm^2$$

$F_{cu} = 25 \ N/mm^2 \longrightarrow F_{co} = 6.0 \ N/mm^2$

$$\text{Allawable Stress} = \frac{F_{co}}{2} = \frac{6.0}{2} = 3.0 \ N/mm^2$$

Actual Stress < Allawable Stress $\longrightarrow t_s = 200$ mm is o.k.

Check Tension Stresses.

$(T_{max}) = 284.68$ kN/m Ten.

$$\text{Actual Stress} = \frac{T_{max}}{A_c} = \frac{T_{max}}{1000 * t_s} = \frac{284.68 * 10^3}{1000 * 200} = 1.423 \ N/mm^2$$

$$\text{Allawable Stress} = \frac{F_{ctr}}{\eta} = \frac{0.6\sqrt{F_{cu}}}{1.7} = \frac{0.6\sqrt{25}}{1.7} = 1.764 \ N/mm^2$$

Actual Stress < Allawable Stress $\longrightarrow$ $t_s = 200$ mm is o.k.

To Get T_1 RFT. $\longrightarrow$ max. Tension $T_1 = 54.54$ kN/m

$$As_{(T_1)} = \frac{T_{2\,(U.L.)}}{F_y \backslash \gamma_s} = \frac{1.5 * 54.54 * 10^3}{360 \backslash 1.15} = 261.33 \ mm^2/m$$

$$As_{(T_1)} \backslash Side = \frac{261.33}{2} = 130.66 \ mm^2/m \xrightarrow{\text{use min. RFT.}} 5\phi 10 \backslash m' \text{ each Side}$$

To Get T_2 RFT. $\longrightarrow$ max. Tension $T_2 = 284.68$ kN/m

$$As_{(T_2)} = \frac{T_{2\,(U.L.)}}{F_y \backslash \gamma_s} = \frac{1.5 * 284.68 * 10^3}{360 \backslash 1.15} = 1364.1 \ mm^2/m$$

$$As_{(T_2)} \backslash Side = \frac{1364.1}{2} = 682.05 \ mm^2/m \xrightarrow{\text{use min. RFT.}} 7\phi 12 \backslash m' \text{ each Side}$$

For Lower Dome. Sec. 7 & Sec. 8 Water Sections.

No Compression Stresses.

Check Tension Stresses.

$(T_{max}) = 277.5$ kN/m Ten.

$$\text{Actual Stress} = \frac{T_{max}}{A_c} = \frac{T_{max}}{1000 * t_s} = \frac{277.5 * 10^3}{1000 * 200} = 1.387 \ N/mm^2$$

$$\text{Allawable Stress} = \frac{F_{ctr}}{\eta} = \frac{0.6\sqrt{F_{cu}}}{1.7} = \frac{0.6\sqrt{25}}{1.7} = 1.764 \ N/mm^2$$

Actual Stress < Allawable Stress $\longrightarrow$ $t_s = 200$ mm is o.k.

To Get T_1 & T_2 RFT. $\longrightarrow$ max. Tension $T_1 = T_2 = 277.5$ kN/m

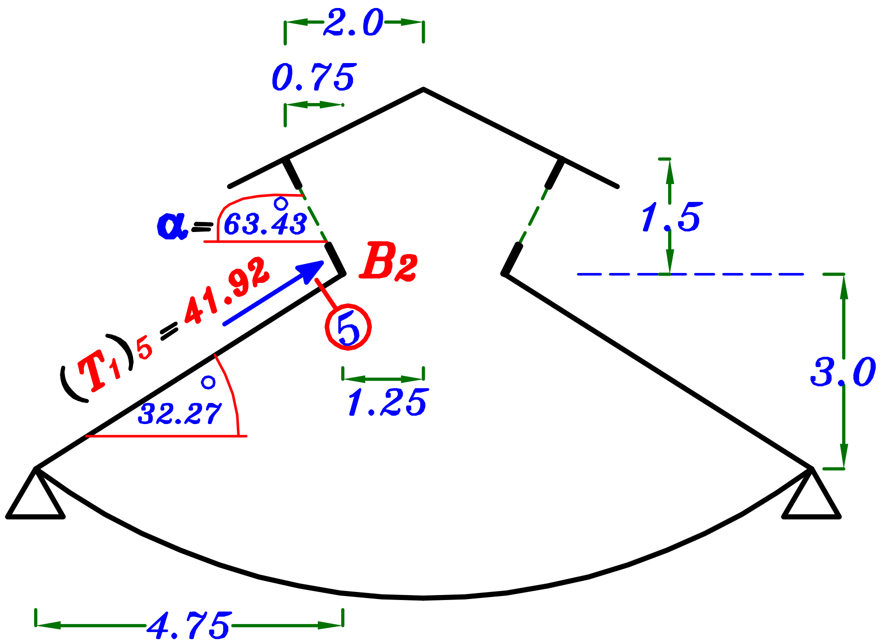
$$As_{(T_1)} = As_{(T_2)} = \frac{T_{(U.L.)}}{F_y \backslash \gamma_s} = \frac{1.5 * 277.5 * 10^3}{360 \backslash 1.15} = 1329.7 \ mm^2/m$$

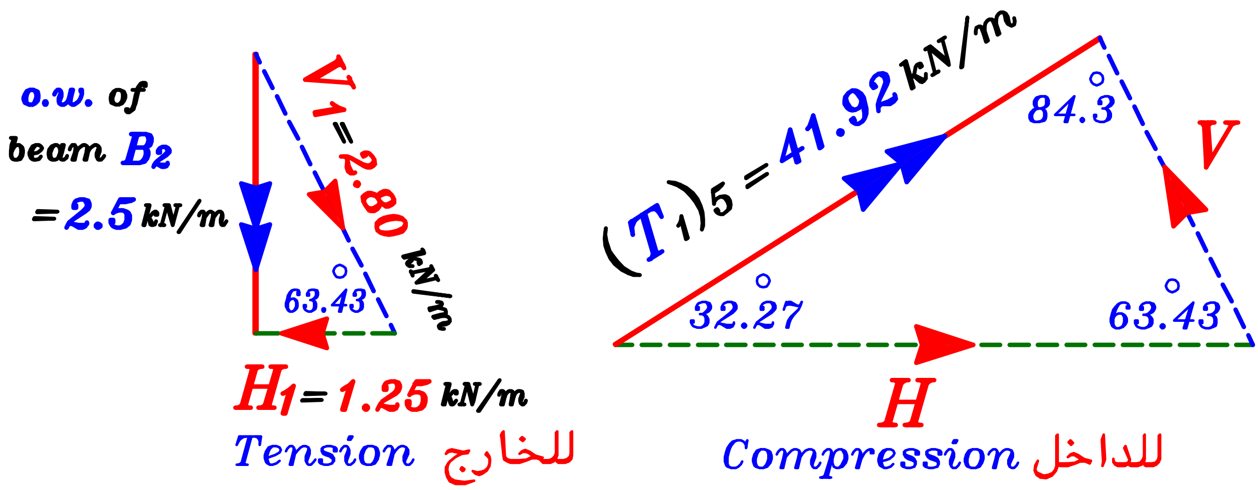
$$As_{(T_1),(T_2)} \backslash Side = \frac{1329.7}{2} = 664.85 \ mm^2/m \xrightarrow{\text{use min. RFT.}} 6\phi 12 \backslash m'$$

each Side

Design of Beam B_2 (250*400)

$o.w.(B_2) = 2.50\ kN/m$





Using Sin Rule

$$\frac{41.92}{\sin 63.43°} = \frac{V}{\sin 32.27°} = \frac{H}{\sin 84.30°}$$

$$\boxed{V = 25.02\ kN/m} \qquad \boxed{H = 46.64\ kN/m}$$

VL. Load on beam $B_2 = V - V_1 = 25.02 - 2.80 = 22.22\ kN/m$

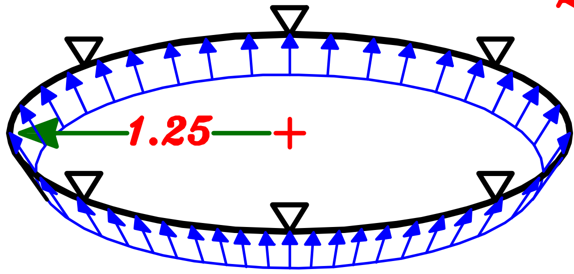
HL. Load on beam $B_2 = H - H_1 = 46.64 - 1.25 = 45.39\ kN/m$

Compression للداخل

Compression Force on Beam $= HL.\ Load * r = 45.39 * 1.25$

$= 56.73\ kN$ Comp.

$$P = 56.73 \text{ kN}$$ Comp.



From Tables $n = 6.0$

No. of supports	Load on each support	Max. Shearing Force	Max. Bending Moment at C.L. of Span	Max. Bending Moment Over C.L. of Column	Max. Torsional Moment	Central angle
n	R	$Q_{max.}$	M_{+Ve}	M_{-Ve}	$M_{t\,max.}$	θ
4	P/4	P/8	0.0176 Pr	– 0.0322 Pr	0.0053 Pr	19° 21`
6	P/6	P/12	0.0075 Pr	– 0.0148 Pr	0.0015 Pr	12° 44`
8	P/8	P/16	0.0042 Pr	– 0.0083 Pr	0.0006 Pr	9° 33`
10	P/10	P/20	0.0032 Pr	– 0.0052 Pr	0.0004 Pr	7° 36`
12	P/12	P/24	0.0019 Pr	– 0.0037 Pr	0.0002 Pr	6° 21`

لان الحمل الرأسى يؤثر على الكمره من اسفل الى اعلى
سيكون اتجاه و قيمه كلا من (max. M_{-Ve}) و (max. M_{+Ve}) سينعكس
و ستكون قيمته فى الجدول هى قيمه العزم الاخر .

$$P = w * 2\pi r = 22.22 * 2\pi * 1.25 = 174.51 \text{ kN}$$

$$\text{max. } M_{+Ve} = 0.0148\, Pr = 0.0148 * 174.51 * 1.25 = 3.23 \text{ kN.m}$$

$$\text{max. } M_{-Ve} = 0.0075\, Pr = 0.0075 * 174.51 * 1.25 = 1.636 \text{ kN.m}$$

$$\text{max. } M_t = 0.0015\, Pr = 0.0015 * 174.51 * 1.25 = 0.327 \text{ kN.m}$$

$$Q_{max.} = \frac{P}{6} = \frac{174.51}{6} = 29.08 \text{ kN}$$

Central angle $\theta = 12^\circ\ 44' = 12.73^\circ$

$$X = r * \theta * \frac{\pi}{180} = 1.25 * 12.73 * \frac{\pi}{180} = 0.277 \text{ m}$$

$$Q_{cor.} = Q_{max} - w * X = 29.08 - 22.22 * 0.277 = 22.92 \text{ kN}$$

Design beam B2 on M & P

$b = 250$ mm , $t = 400$ mm

Sec. of max. + Ve B.M.

$M = 3.23 * 1.5 = 4.845$ kN.m. , $P = 56.73 * 1.5 = 85.10$ kN

Check $\dfrac{P}{F_{cu}\, b\, t} = \dfrac{85.10 * 10^3}{25 * 250 * 400} = 0.034 < 0.04$ (Don't neglect P)

$\therefore d = C_1 \sqrt{\dfrac{M_{U.L.}}{F_{cu}\, b}} \quad \therefore 350 = C_1 \sqrt{\dfrac{4.845 * 10^6}{25 * 250}} \rightarrow C_1 = 12.5 \rightarrow J = 0.826$

$\therefore A_s = \dfrac{M_{U.L.}}{J\, F_y\, d} = \dfrac{4.845 * 10^6}{0.826 * 360 * 350} = 46.55 \text{ mm}^2$

Check $A_{s_{min.}}$ $\qquad A_{s\,req.} = 46.55 \text{ mm}^2$

$\mu_{min.}\, b\, d = \left(0.225 * \dfrac{\sqrt{F_{cu}}}{F_y}\right) b\, d = \left(0.225 * \dfrac{\sqrt{25}}{360}\right) 250 * 350 = 273.43 \text{ mm}^2$

$\therefore \mu_{min.}\, b\, d > A_{s_{req.}} \xrightarrow{\text{Use}} A_{s_{min.}}$

$A_{s_{min.}} = 0.225 * \dfrac{\sqrt{F_{cu}}}{F_y}\, b\, d = \left(0.225 * \dfrac{\sqrt{25}}{360}\right) 250 * 350 = 273.43$

$1.3\, A_{s_{req.}} = 1.3 * 46.55 = 60.51$

الأقل $= 60.51$

st. 360/520 $\qquad \dfrac{0.15}{100}\, b\, d = \dfrac{0.15}{100} * 300 * 350 = 157.5 \text{ mm}^2$

الأكبر $= 157.5 \text{ mm}^2$

Sec. of max. − Ve B.M.

$M = 1.636 * 1.5 = 2.45$ kN.m.

Take $A_s = A_{s_{min.}} = 157.5 \text{ mm}^2$

Design due to Shear & Torsion.

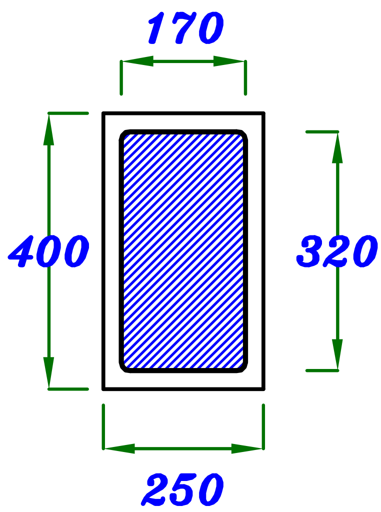
$$q_u = \frac{Q}{b\,d} = \frac{1.5 * 22.92 * 10^3}{250 * 350} = 0.393\ N/mm^2$$

$$A_{oh} = 170 * 320 = 54400\ mm^2$$

$$A_o = 0.85 * A_{oh} = 0.85 * 54400 = 46240\ mm^2$$

$$P_h = 2 * 170 + 2 * 320 = 980\ mm$$

$$t_e = \frac{A_{oh}}{P_h} = \frac{54400}{980} = 55.51\ mm$$



$$q_{tu} = \frac{M_{tu}}{2\,A_o\,t_e} = \frac{1.5 * 0.327 * 10^6}{2 * 46240 * 55.51} = 0.095\ N/mm^2$$

$$q_{cu} = (0.24)\sqrt{\frac{25}{1.5}} = 0.98\ N/mm^2$$

$$q_{t\,min} = (0.06)\sqrt{\frac{25}{1.5}} = 0.245\ N/mm^2$$

$$q_{u\,max} = (0.7)\sqrt{\frac{25}{1.5}} = 2.85\ N/mm^2$$

$$\sqrt{q_u^2 + q_{tu}^2} = \sqrt{0.393^2 + 0.095^2} = 0.404\ N/mm^2 < q_{u\,max} \quad \therefore o.k.$$

$\boxed{q_u < q_{cu}\ ,\ q_{tu} < q_{t\,min}}$ $\therefore$ Use min. Stirrups $\boxed{5\phi 8 \backslash m'}$

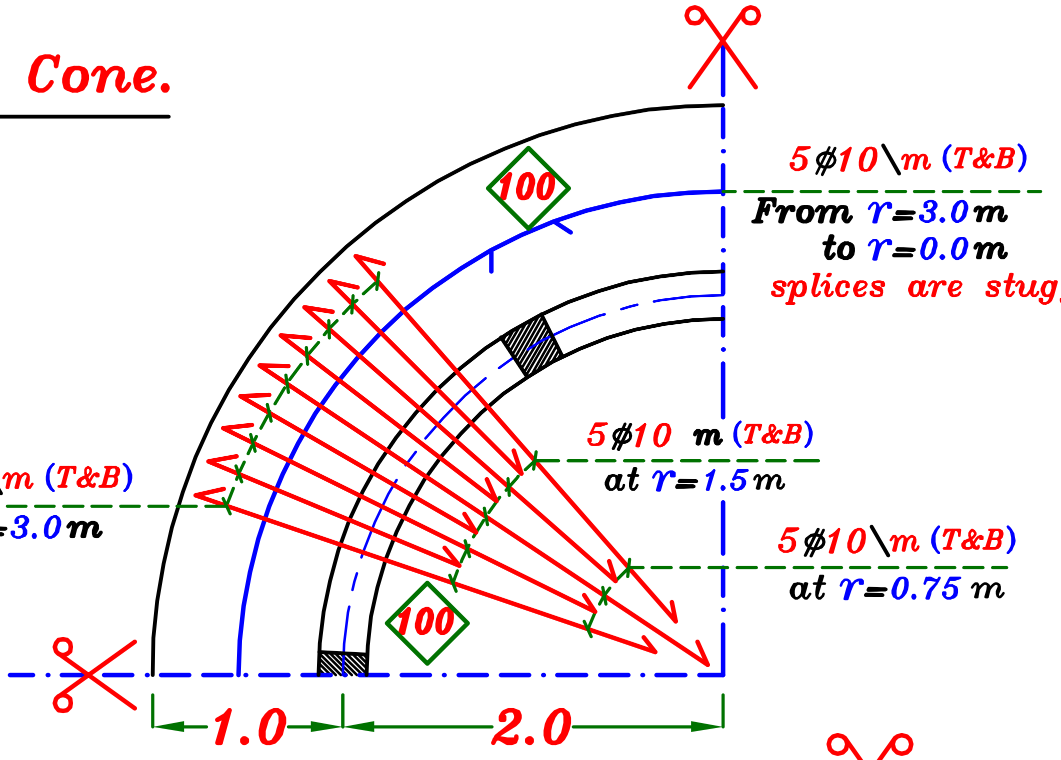
2 branches.

No need to use Longitudinal Bars

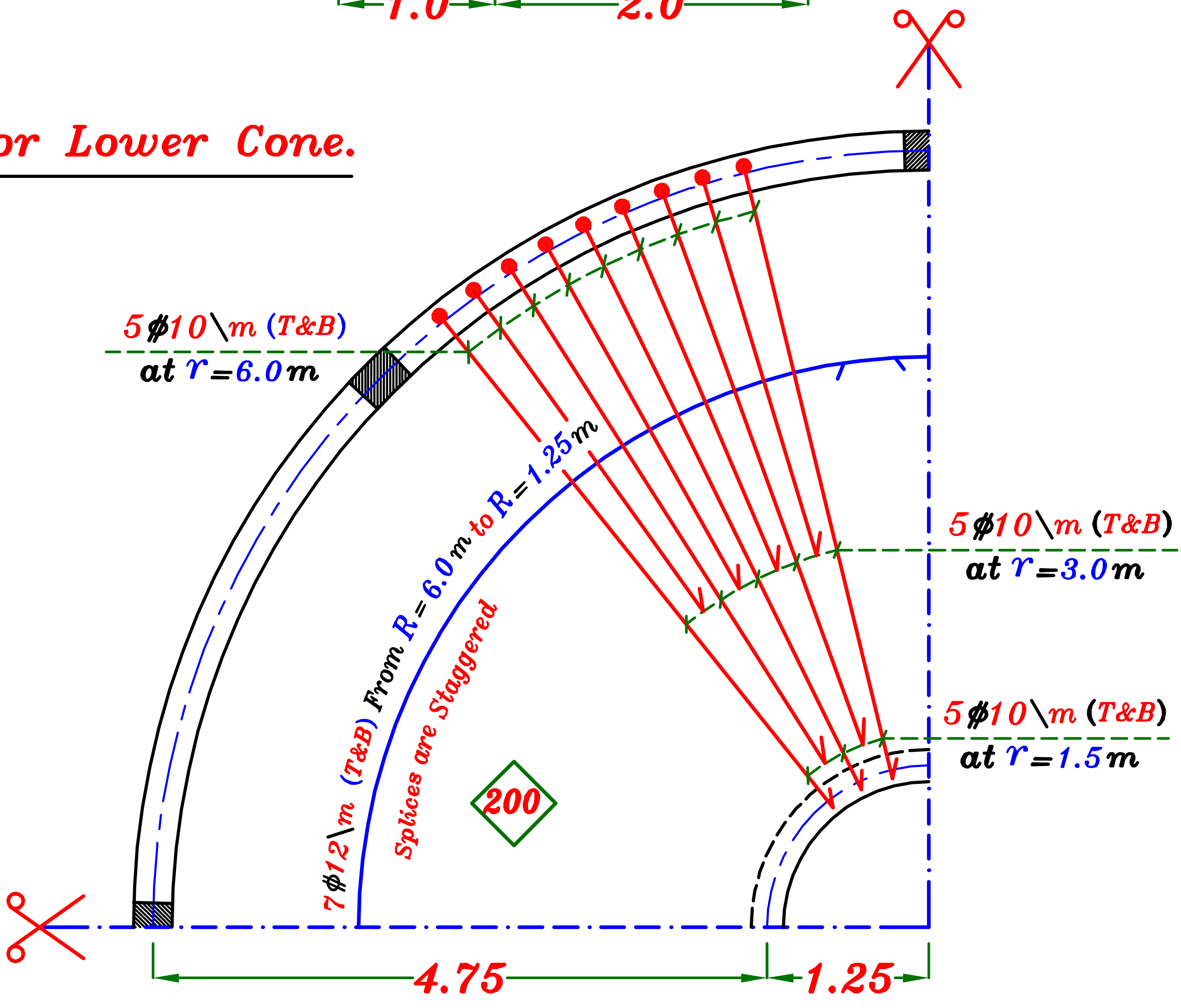
$$A_{s\,total} = A_s = 157.5\ mm^2$$ 2 ϕ 12

Details of RFT.

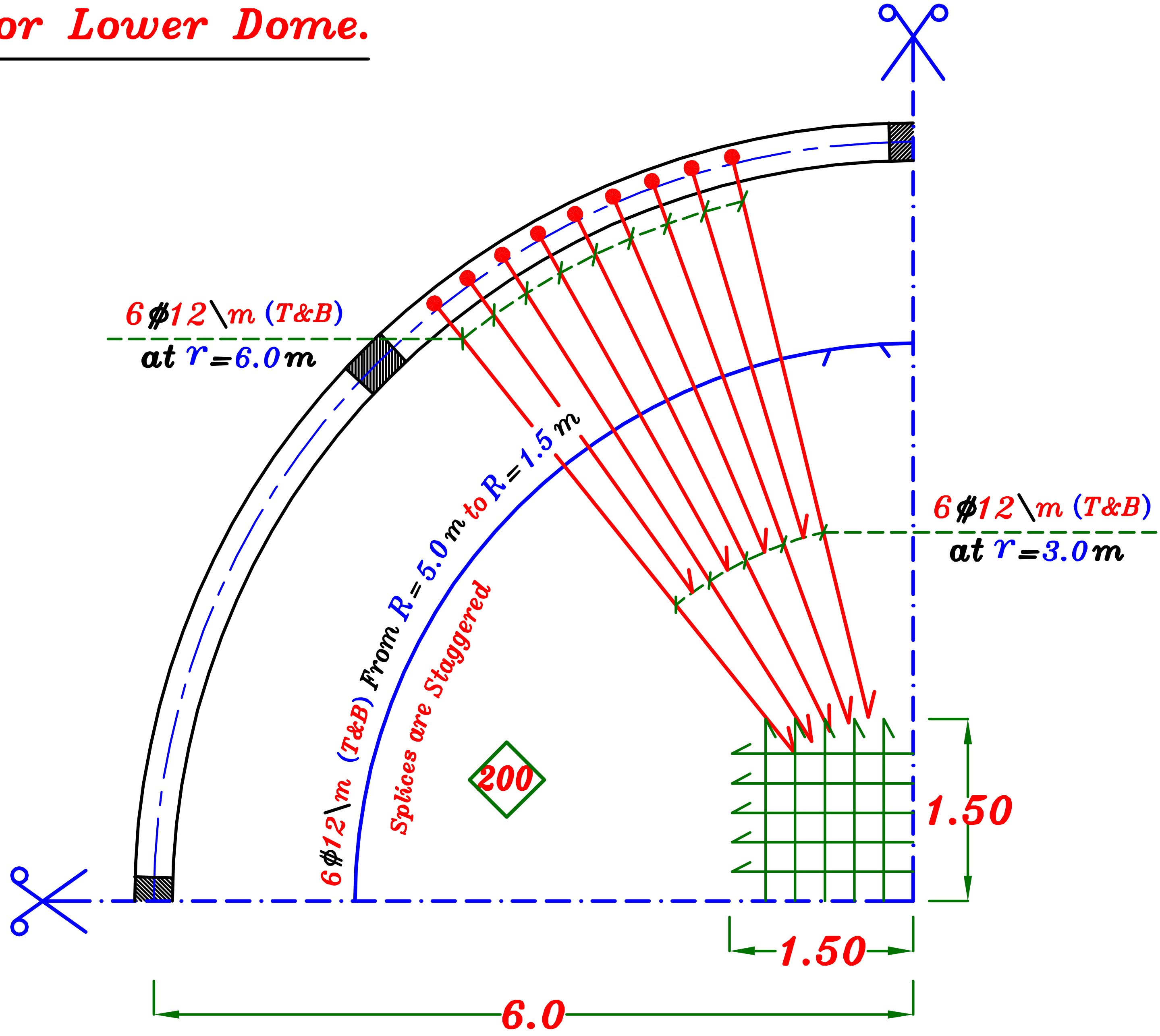
For Upper Cone.



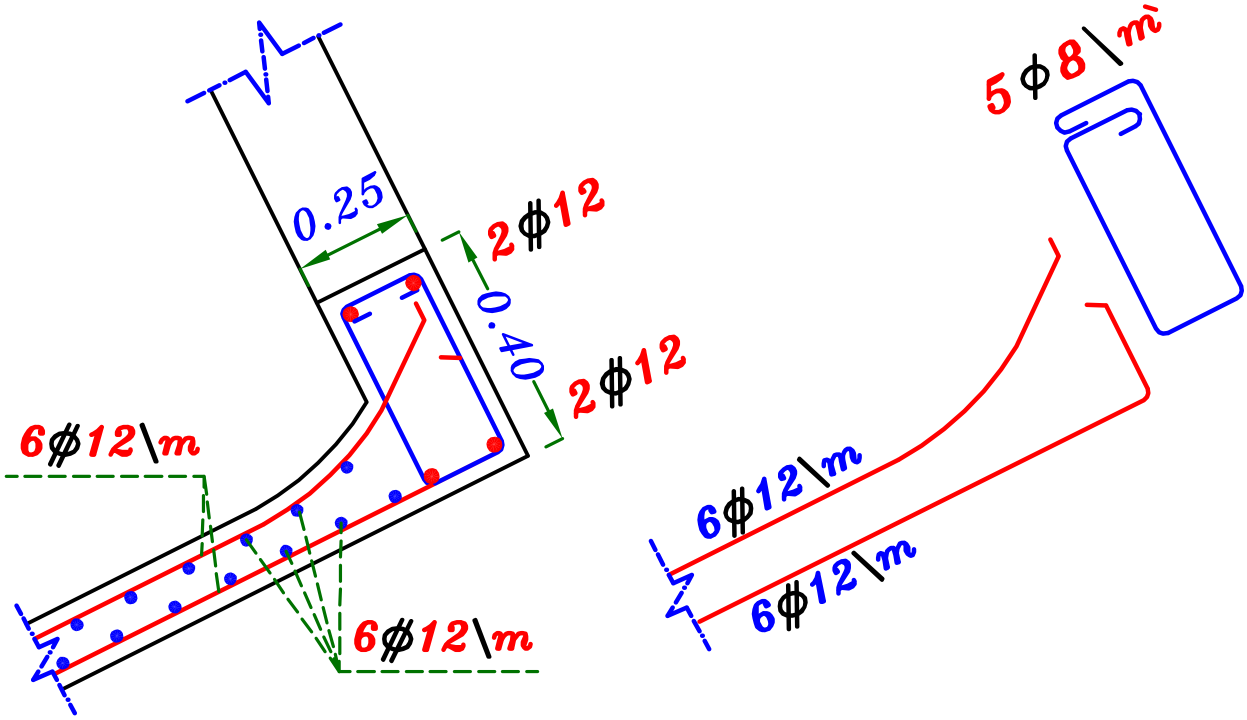
For Lower Cone.



For Lower Dome.



Section at B_2



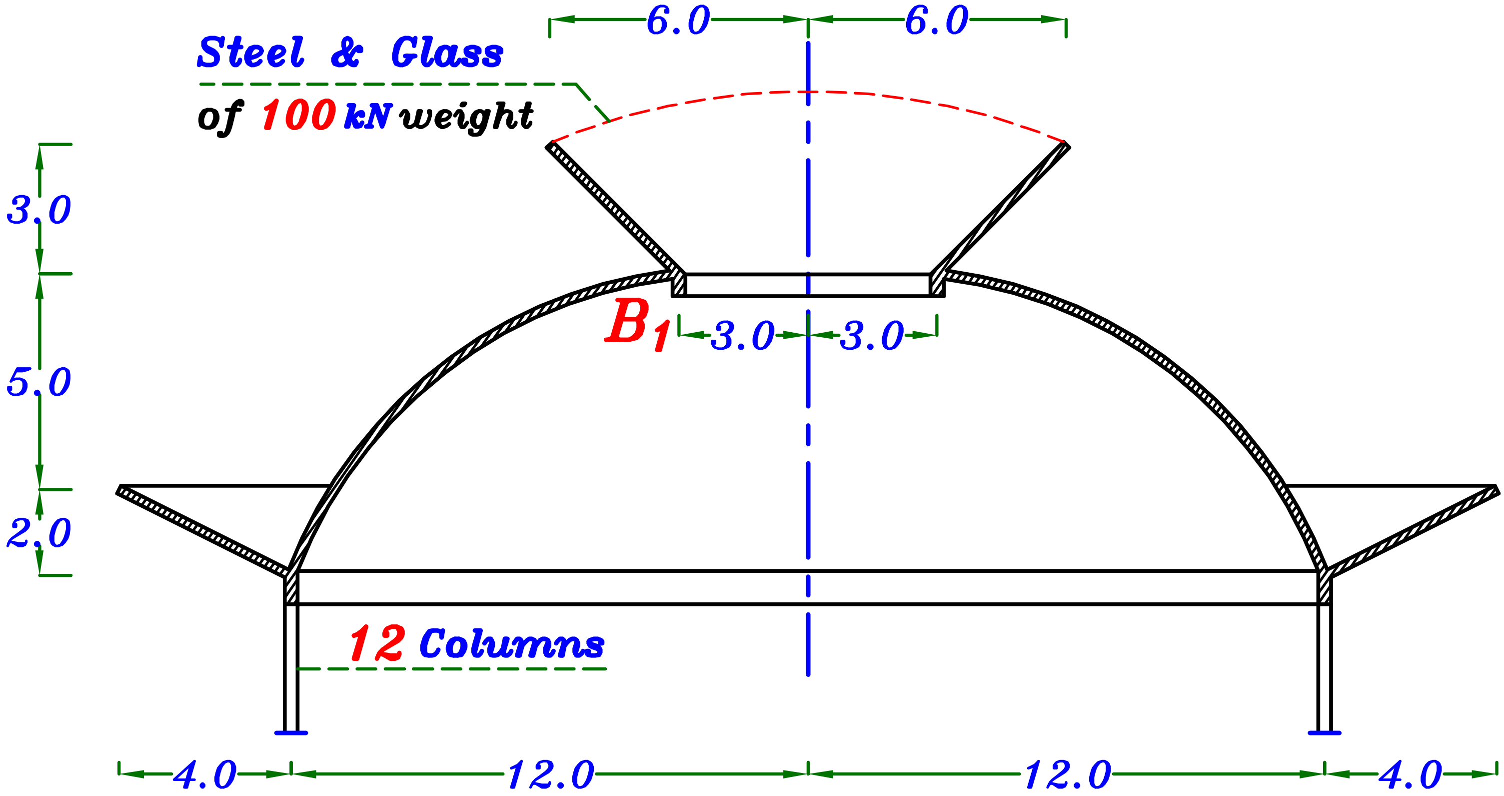
Example.

Design the supporting beam B_1

Given:

$F.C. = 1.0\ kN/m^2$, $L.L. = 1.0\ kN/m^2$ (H.P.)

$F_{cu} = 30\ N/mm^2$, st. 360/520



Solution.

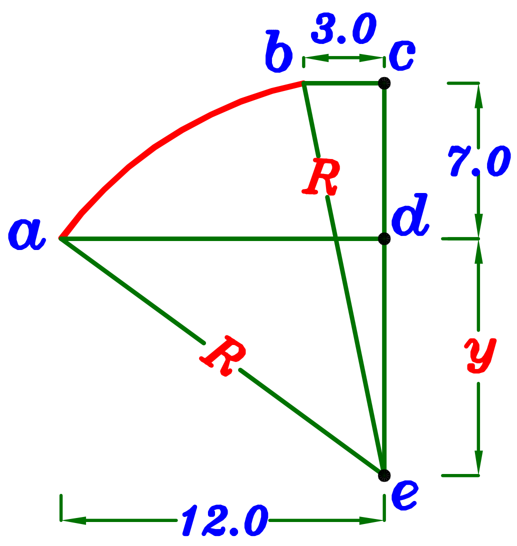
Choose $t_s = 100\ mm \longrightarrow 140\ mm$ Take $\boxed{t_s = 120\ mm}$

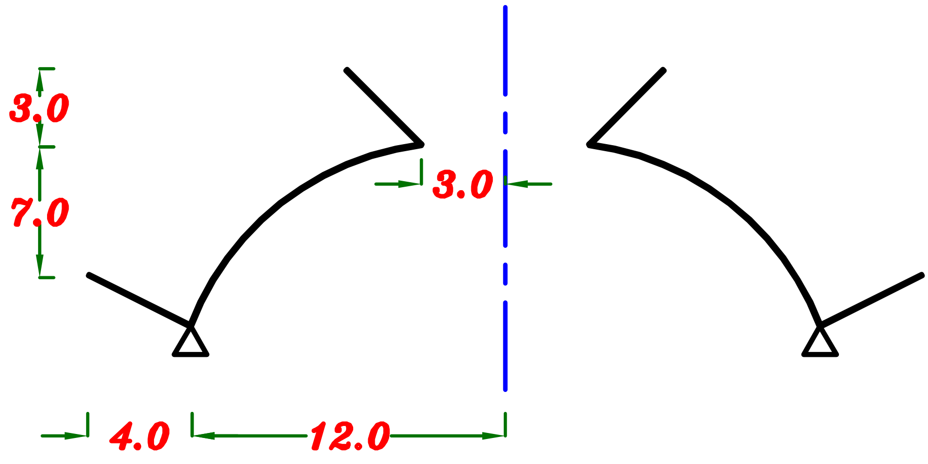
Loads.

$$g_s = t_s\,\gamma_c + F.C. = 0.12 * 25 + 1.0 = 4.0\ kN/m^2$$

$$p_s = 1.0\ kN/m^2$$

For Dome.





For Triangle ade

$$R^2 = 12.0^2 + y^2 \qquad \therefore R^2 = 144 + y^2 \quad \underline{R,y} \text{ ------- } (1)$$

For Triangle ecb

$$R^2 = 3.0^2 + (y + 7.0)^2 \longrightarrow R^2 = 9.0 + y^2 + 14.0\,y + 49.0$$

$$R^2 = 58.0 + y^2 + 14.0\,y \quad \underline{R,y} \text{ ------- } (2)$$

بتعويض R^2 من المعادله الاولى فى المعادله الثانيه

$$\therefore 144 + \cancel{y}^2 = 58.0 + \cancel{y}^2 + 14.0\,y \longrightarrow y = 6.143\ m$$

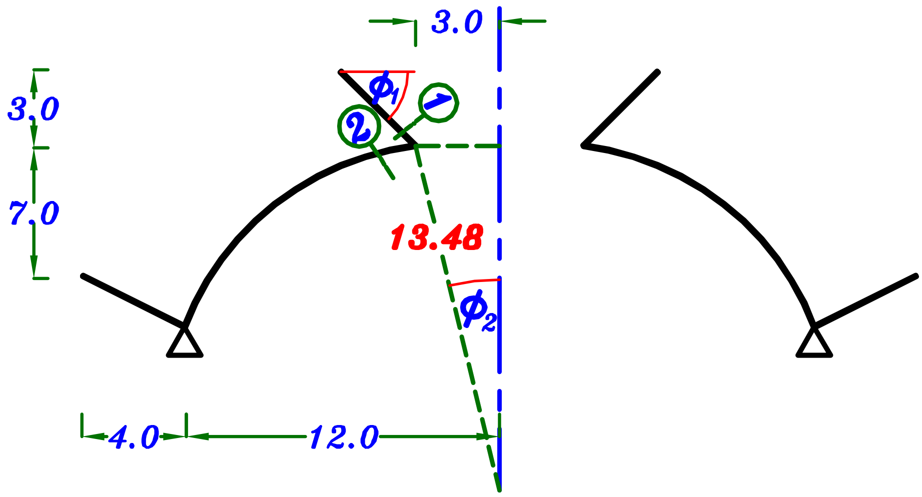
$$\therefore R^2 = 144 + 6.143^2 = 181.74\ m^2 \longrightarrow \boxed{R = 13.48\ m}$$

$$\tan \phi_1 = \frac{3.0}{3.0}$$

$$\boxed{\phi_1 = 45.0^\circ}$$

$$\sin \phi_2 = \frac{3.0}{13.48}$$

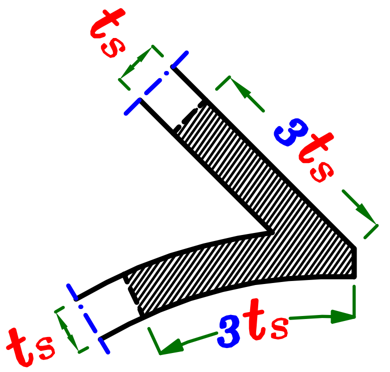
$$\boxed{\phi_2 = 12.86^\circ}$$



For B_1

لو لم يكن شكل القطاع معطى فى المسأله لكنا اعتبرناها كمره مدفونه

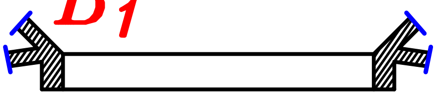
و لن نحسب لها o.w. حيث سيدخل وزنها فى حسابات ال W_ϕ للاسطح



B_1

$$A_c = 3\,t_s * t_s + 3\,t_s * t_s = 6\,t_s^{\,2}$$

B_1

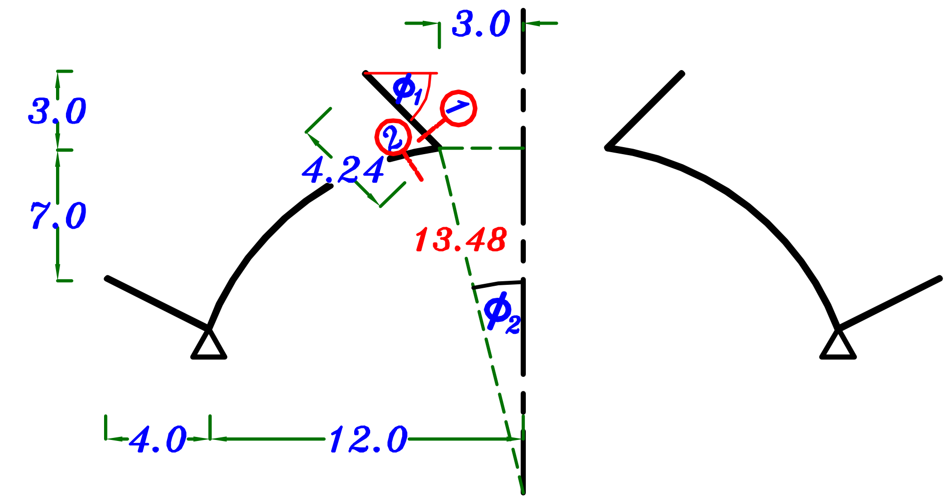


و لكن لان قطاع الكمره مرسوم فى المسأله

فسنأخذ شكل قطاع الكمره مستطيل كما بالرسمه

Take the Beam $(300 * 700)$

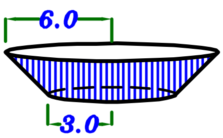
$$o.w._{(B_1)} = b * t * \gamma_c = 0.30 * 0.70 * 25 = 5.25 \ kN/m$$



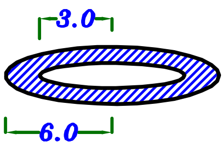
For Sec. 1

$r = 3.0\ m$ $\boxed{\phi = 12.86^\circ}$

$$S.A. = \pi * L\,(a+b) = \pi * 4.24 * (6.0 + 3.0) = 119.88\ m^2$$



$$\text{Projected area} = \pi * (r_1^2 - r_2^2) = \pi * (6.0^2 - 3.0^2) = 84.82\ m^2$$



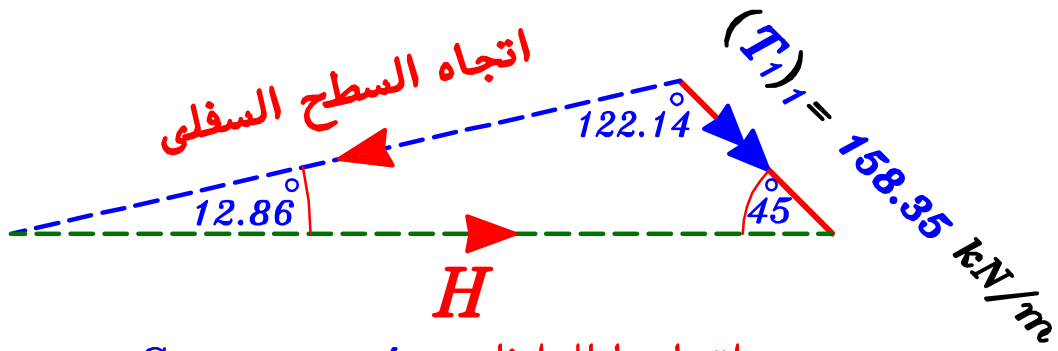
$$W_{\phi} = \text{Steel \& Glass Weight} + g * S.A. + p * \text{Projected area}$$

$$= 100 + 4.0 * 119.88 + 1.0 * 84.82 = +664.34 \ kN$$

$$(T_1)_1 = \frac{W_{\phi}}{2\pi r \ \sin\phi} = \frac{664.34}{2\pi * 3.0 * \sin 12.86^{\circ}} = +158.35 \ kN/m \ \text{Comp.}$$

Straining Actions on B_1

نقوم بتحليل القوه (T_1) للسطح المحمول الى مركبتين احداهما فى اتجاه السطح الحامل و الاخرى فى الاتجاه الافقى .

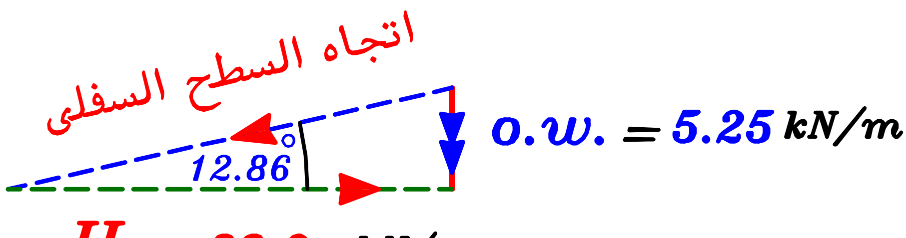


Compression اتجاهها للداخل

$$\frac{H}{\sin \ 122.14^{\circ}} = \frac{158.35}{\sin \ 12.86^{\circ}} \longrightarrow H = 602.44 \ kN/m \ \text{Comp.}$$

و نقوم بتحليل $o.w.$ الكمره الى مركبتين احداهما فى اتجاه السطح الحامل و الاخرى فى الاتجاه الافقى .

$$o.w._{(B_1)} = b * t * \gamma_c = 0.30 * 0.70 * 25 = 5.25 \ kN/m \ \ \text{Comp.}$$



$H_1 = 23.0 \ kN/m$

Compression اتجاهها للداخل

$$H_{total} = H + H_1 = 602.44 + 23.0 = 625.44 \text{ kN/m Comp.}$$

Compression Force on Beam $= H_{total} * r$

$$= 625.44 * 3.0 = 1876.32 \text{ kN}$$

$$A_c = 300 * 700 = 210000 \text{ mm}^2$$

$$P_{U.L.} = 1876.32 * 1.5 = 2814.48 \text{ kN}$$

Design the HL. Beam as short Column

$$P_{U.L.} = 0.35\, A_c\, F_{cu} + 0.67\, A_s\, F_y$$

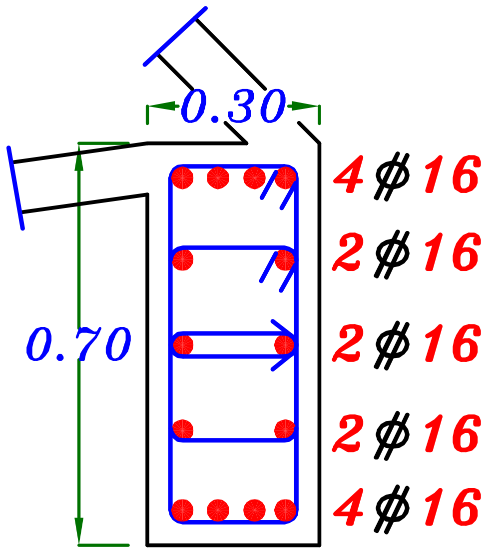
$$\therefore 2814.48 * 10^3 = 0.35(210000)\,(30) + 0.67\, A_s\,(360)$$

$$\therefore A_s = 2526.87 \text{ mm}^2$$

Check $A_{s_{min.}} = \dfrac{0.80}{100} * A_c = \dfrac{0.80}{100} * 210000 = 1680 \text{ mm}^2$

$$\therefore A_s > A_{s_{min.}} \quad \therefore \text{o.k.}$$

$$\therefore A_s = 2526.87 \text{ mm}^2 \quad \boxed{14 \phi 16}$$



Example.

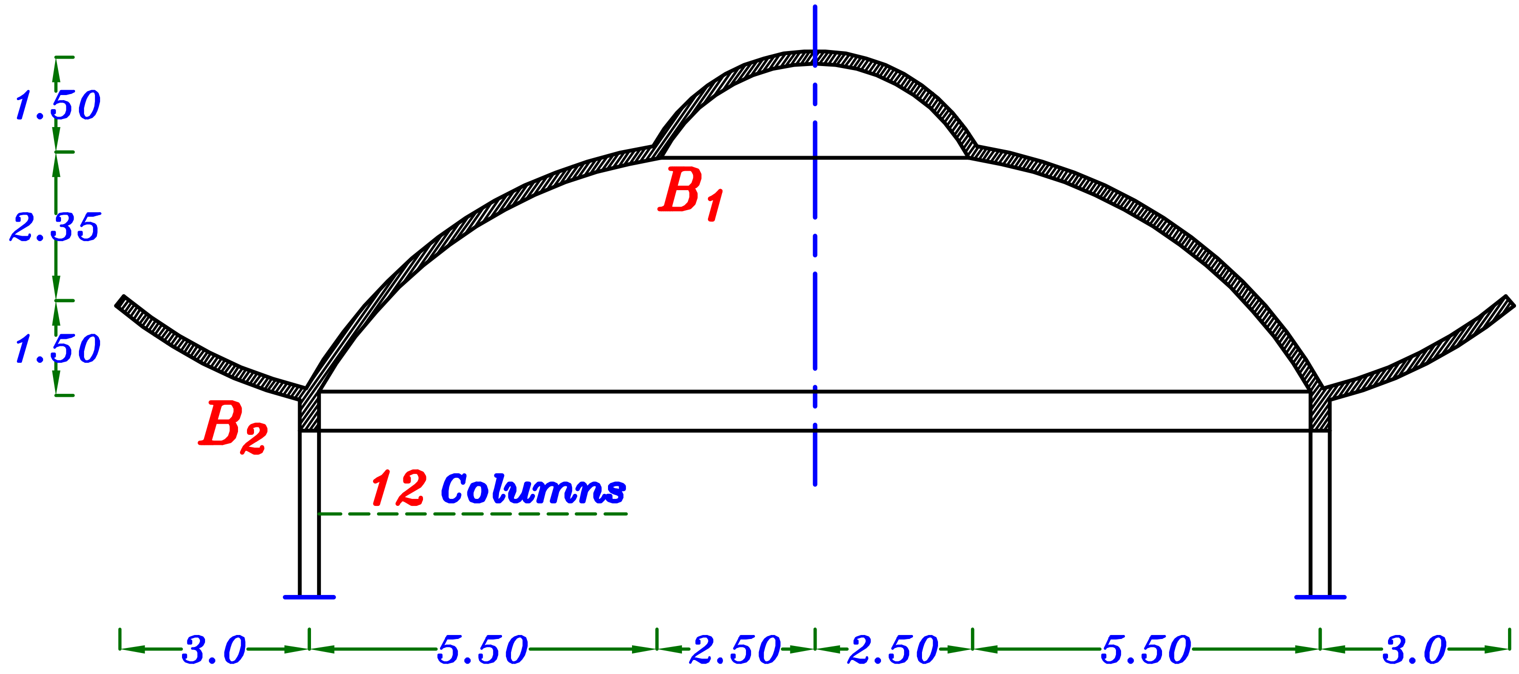
1 – Design the supporting beam B_1

2 – Draw a Sketch illustrate the FRT. of Surfaces in Plan.

Given:

$F.C. = 1.0 \ kN/m^2$, $L.L. = 1.0 \ kN/m^2$ (H.P.)

$F_{cu} = 30 \ N/mm^2$, st. 360/520



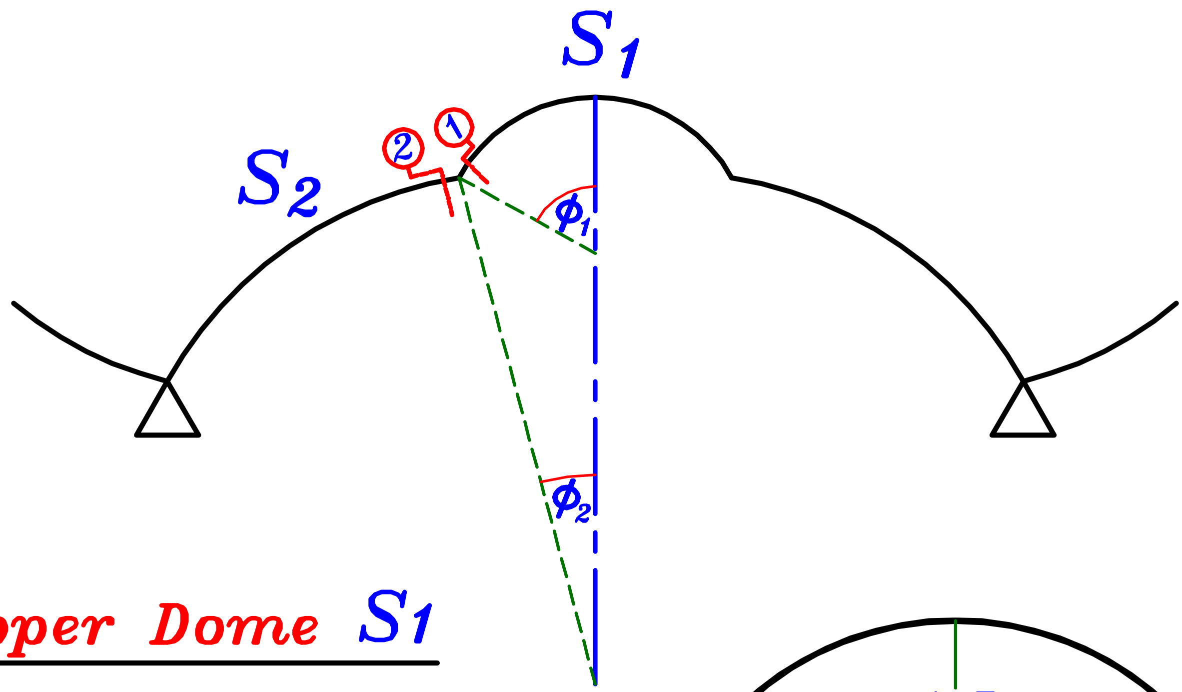
Solution.

Choose $t_s = 100 \ mm \longrightarrow 140 \ mm$ Take $\boxed{t_s = 100 \ mm}$

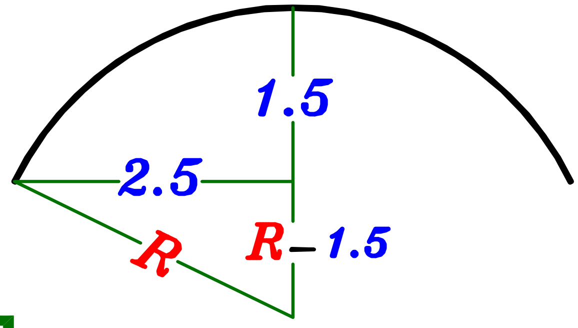
Loads.

$$g_s = t_s \gamma_c + F.C. = 0.10 * 25 + 1.0 = 3.5 \ kN/m^2$$

$$p_s = 1.0 \ kN/m^2$$



For Upper Dome S1

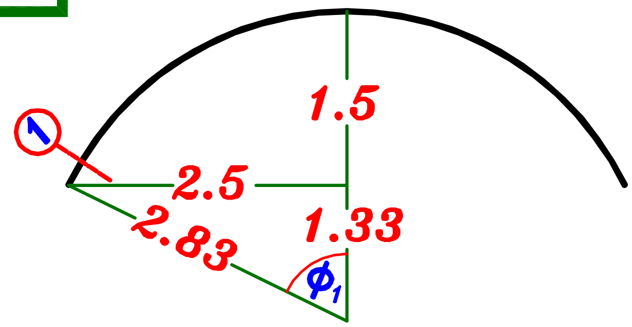


$$R^2 = 2.5^2 + (R - 1.5)^2$$

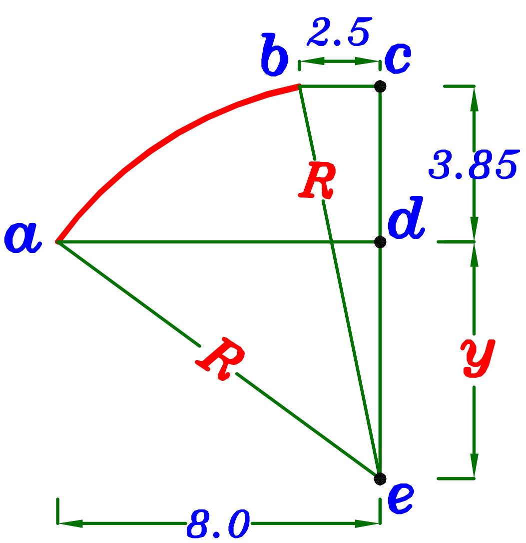
$$\cancel{R^2} = 6.25 + \cancel{R^2} - 3.0\,R + 2.25$$

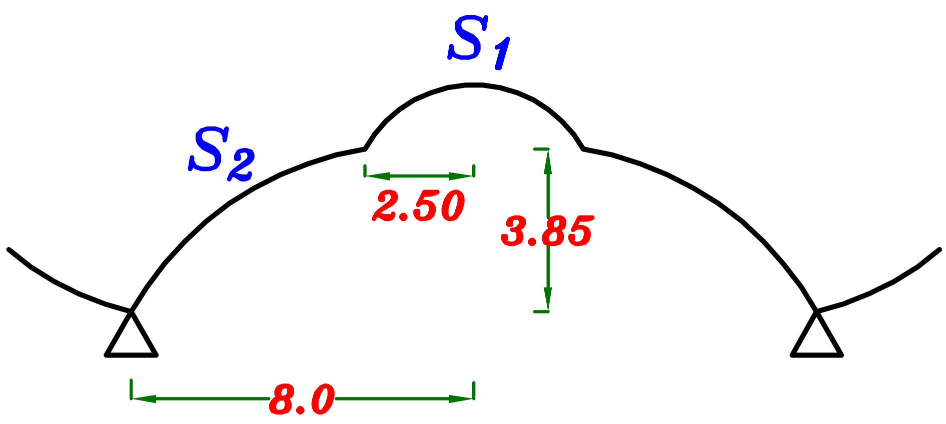
$$3.0\,R = 8.50 \longrightarrow \boxed{R = 2.83\,m}$$

$$Sin\phi_1 = \frac{2.5}{2.83} \longrightarrow \boxed{\phi_1 = 62.05^\circ}$$



For middle Dome S2





For Triangle ade

$$R^2 = 8.0^2 + y^2 \qquad \therefore R^2 = 64 + y^2 \quad \underline{R, y} \text{------} (1)$$

For Triangle ecb

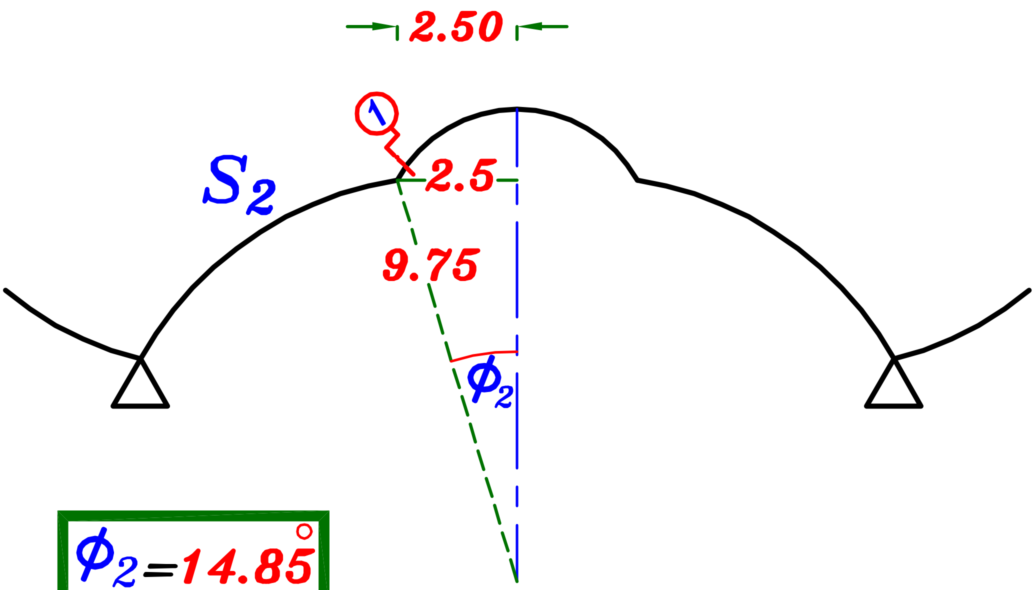
$$R^2 = 2.5^2 + (y + 3.85)^2 \longrightarrow R^2 = 6.25 + y^2 + 7.7\,y + 14.82$$

$$R^2 = 21.07 + y^2 + 7.7\,y \quad \underline{R, y} \text{------} (2)$$

بتعويض R^2 من المعادله الاولى فى المعادله الثانيه

$$\therefore 64 + \cancel{y}^2 = 21.07 + \cancel{y}^2 + 7.7\,y \longrightarrow y = 5.575\ m$$

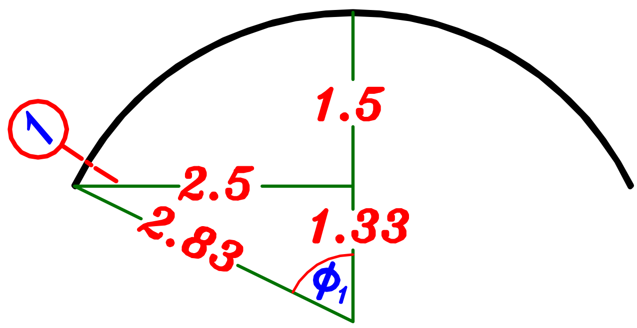
$$\therefore R^2 = 64 + 5.575^2 = 95.08\ m^2 \longrightarrow \boxed{R = 9.75\ m}$$

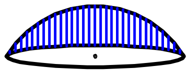


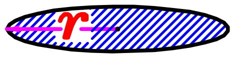
$$Sin\,\phi_2 = \frac{2.5}{9.75} \qquad \boxed{\phi_2 = 14.85^\circ}$$

For Sec. (1)

$$r = 2.5\ m \qquad \boxed{\phi = 62.05^\circ}$$



$S.A. = 2\pi * R * h$  $= 2\pi * 2.83 * 1.5 = 26.67\ m^2$

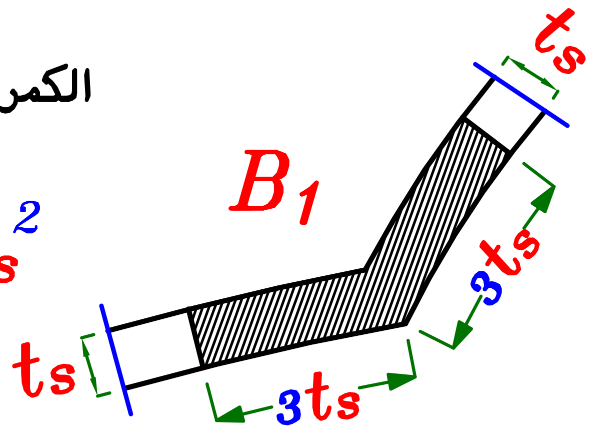
$Projected\ area = \pi * r^2$  $= \pi * 2.5^2 = 19.634\ m^2$

$$W_\phi = g * S.A. + p * Projected\ area$$

$$= 3.5 * 26.67 + 1.0 * 19.634 = +112.98\ kN$$

$$(T_1)_1 = \frac{W_\phi}{2\pi r\ Sin\phi} = \frac{+112.98}{2\pi * 2.5 * Sin\ 62.05^\circ} = +\ 8.142\ kN/m\ \text{Comp.}$$

For B_1 الكمره المدفونه بين السطحين

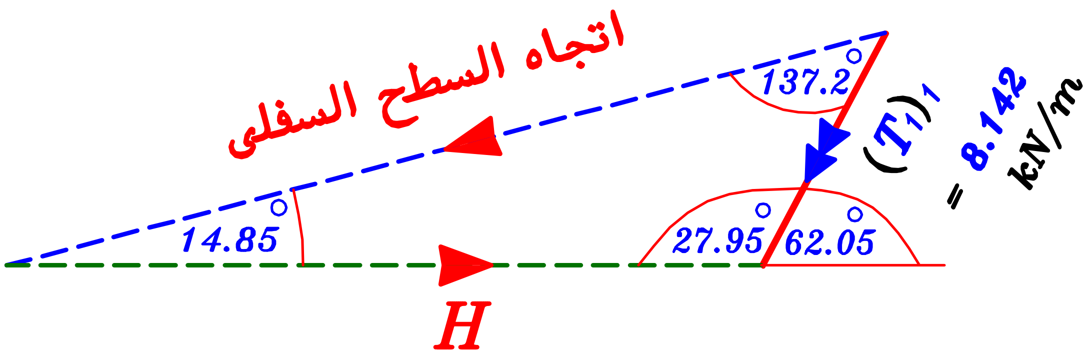


$$A_c = 3t_s * t_s + 3t_s * t_s = 6t_s^2$$

لن نحسب لها $o.w.$ حيث سيدخل وزنها فى حسابات الـ W_ϕ للاسطح

Straining Actions on B_1

نقوم بتحليل القوه (T_1) للسطح المحمول الى مركبتين احداهما فى اتجاه السطح الحامل و الاخرى فى الاتجاه الافقى .



Compression اتجاهها للداخل

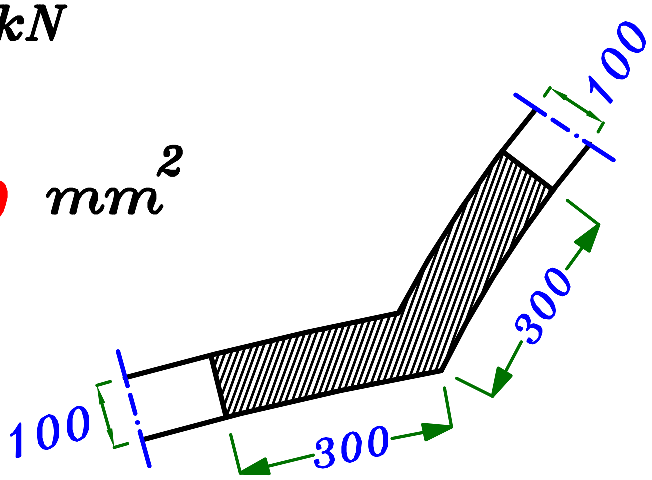
$$\frac{H}{Sin\ 137.2^\circ} = \frac{8.142}{Sin\ 14.85^\circ} \longrightarrow H = 21.58\ kN/m\ \text{Comp.}$$

Compression Force on Beam $= H * \gamma$

$= 21.58 * 2.5 = 53.95$ kN

$$P_{U.L.} = 53.95 * 1.5 = 80.925 \text{ kN}$$

$$A_c = 6 t_s^2 = 6 * 100^2 = 60000 \text{ mm}^2$$



Design the HL. Beam as short Column

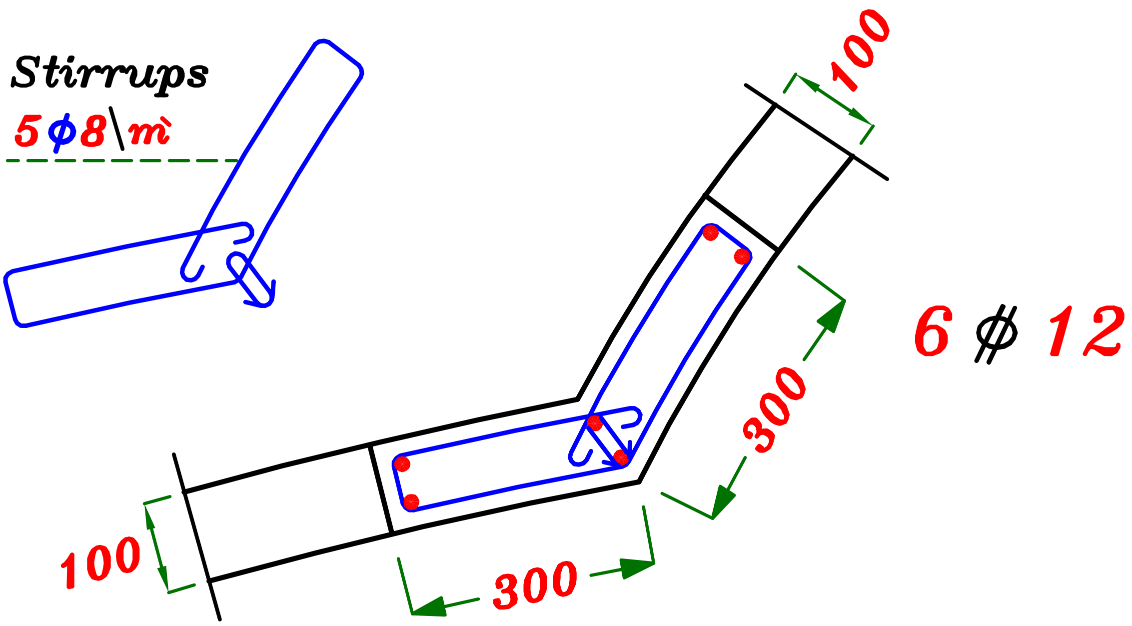
$$P_{U.L.} = 0.35 A_c F_{cu} + 0.67 A_s F_y$$

$$\therefore 80.925 * 10^3 = 0.35 (60000)(30) + 0.67 A_s (360)$$

$$\therefore A_s = -2276.4 \text{ mm}^2$$

$$\therefore \text{Take } A_s = A_{s_{min.}} = \frac{0.80}{100} * A_c = \frac{0.80}{100} * 60000 = 480 \text{ mm}^2$$

$\boxed{6 \phi 12}$



Sketch of Surfaces RFT. in Plan.